Naval Postgraduate School
Monterey, California 93943-5138

NPS-09-02-029

SUMMARY OF RESEARCH 2001

Institute for Defense Systems Engineering and Analysis (IDSEA)
Phil DePoy
Director

Institute for Information Innovation and Superiority (I2SI)
Cynthia Irvine
Director

The Modeling, Virtual Environments and Simulation (MOVES) Institute
Michael Zyda
Director

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NAVAL POSTGRADUATE SCHOOL
Monterey, California

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This report contains project summaries of the research projects in the Institute for Defense Systems Engineering and Analysis (IDSEA), Institute for Information Superiority and Innovation (I2SI) and The Modeling, Virtual Environments and Simulation (MOVES) Institute. A list of recent publications is also included, which consists of conference presentations and publications, books, contributions to books, published journal papers, and technical reports. Thesis abstracts of students advised by faculty in the Department are also included.

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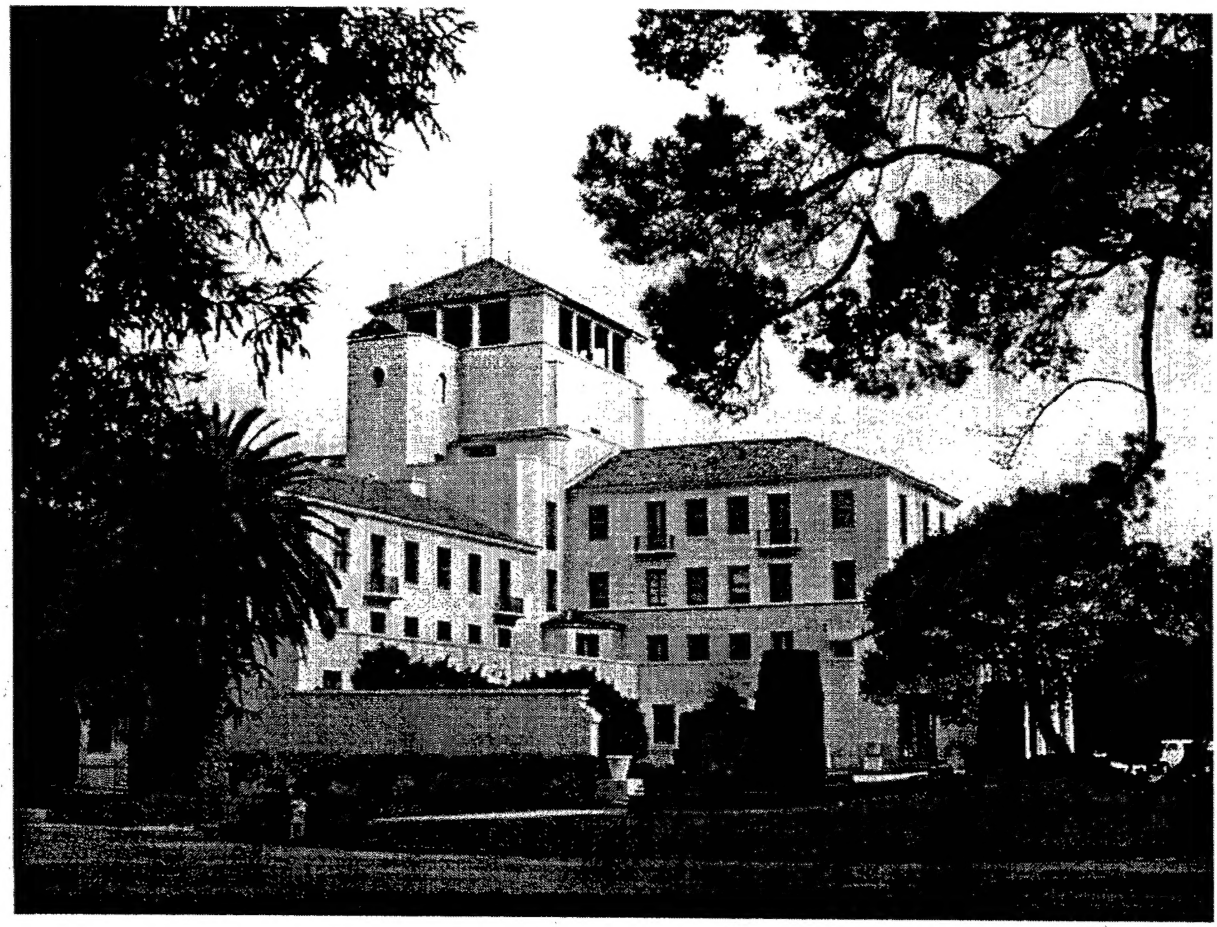

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PREFACE

Research at the Naval Postgraduate School is carried out by faculty in the four graduate schools (School of International Graduate Studies, Graduate School of Operations and Information Sciences, Graduate School of Engineering and Applied Sciences, and Graduate School of Business and Public Policy) and three Research Institutes (Institute for Defense System Engineering and Analysis (IDSEA), Institute for Information Superiority and Innovation (I2SI) and The Modeling, Virtual Environments, and Simulation (MOVES) Institute). This volume contains research summaries for the projects undertaken by faculty in the Institute for Defense Systems Engineering and Analysis (IDSEA), Institute for Information Superiority and Innovation (I2SI) and The Modeling, Virtual Environments and Simulation (MOVES) Institute during 2001. The summary also contains thesis abstracts for those students advised by the Institute for Defense Systems Engineering and Analysis (IDSEA), Institute for Information Superiority and Innovation (I2SI) and The Modeling, Virtual Environments and Simulation (MOVES) Institute faculty during 2001.

Questions about particular projects may be directed to the faculty Principal Investigator listed, the Department Chair, or the Department Associate Chair for Research. Questions may also be directed to the Office of the Associate Provost and Dean of Research. General questions about the Naval Postgraduate School Research Program should be directed to the Office of the Associate Provost and Dean of Research at (831) 656-2099 (voice) or research@nps.navy.mil (e-mail). Additional information is also available at the RESEARCH AT NPS website, http://web.nps.navy.mil/~code09/

Additional published information on the Naval Postgraduate School Research Program can be found in:

- *Compilation of Theses Abstracts:* A quarterly publication containing the abstracts of all unclassified theses by Naval Postgraduate School students.
- *Naval Postgraduate School Research*: A tri-annual (February, June, October) newsletter highlighting Naval Postgraduate School faculty and student research.
- *Summary of Research*: An annual publication containing research summaries for projects undertaken by the faculty of the Naval Postgraduate School.

This publication and those mentioned above can be found on-line at:
http://web.nps.navy.mil/~code09/publications.html.

INTRODUCTION

The research program at the Naval Postgraduate School exists to support the graduate education of our students. It does so by providing military relevant thesis topics that address issues from the current needs of the Fleet and Joint Forces to the science and technology that is required to sustain the long-term superiority of the Navy/DoD. It keeps our faculty current on Navy/DoD issues, and maintains the content of the upper division courses at the cutting edge of their disciplines. At the same time, the students and faculty together provide a very unique capability within the DoD for addressing warfighting problems. Our officers must be able to think innovatively and have the knowledge and skills that will let them apply technologies that are being rapidly developed in both the commercial and military sectors. Their unique knowledge of the operational Navy, when combined with a challenging thesis project that requires them to apply their focused graduate education, is one of the most effective methods for both solving Fleet problems and instilling the life-long capability for applying basic principles to the creative solution of complex problems.

The research program at the Naval Postgraduate School consists of both reimbursable (sponsored) and institutionally funded research. The research varies from very fundamental to very applied, from unclassified to all levels of classification.

- Reimbursable (Sponsored) Program: This program includes those projects externally funded on the basis of proposals submitted to outside sponsors by the School's faculty. These funds allow the faculty to interact closely with RDT&E program managers and high-level policymakers throughout the Navy, DoD, and other government agencies as well as with the private sector in defense-related technologies. The sponsored program utilizes Cooperative Research and Development Agreements (CRADAs) with private industry, participates in consortia with government laboratories and universities, provides off-campus courses either on-site at the recipient command, by VTC, or web-based, and provides short courses for technology updates.

- Naval Postgraduate School Institutionally Funded Research (NIFR) Program: The institutionally funded research program has several purposes: (1) to provide the initial support required for new faculty to establish a Navy/DoD relevant research area, (2) to provide support for major new initiatives that address near-term Fleet and OPNAV needs, (3) to enhance productive research that is reimbursably sponsored, and (4) to cost-share the support of a strong post-doctoral program.

In 2001, the level of research effort overall at the Naval Postgraduate School was 148 faculty work years and exceeded $48 million. The reimbursable program has grown steadily to provide the faculty and staff support that is required to sustain a strong and viable graduate school in times of reduced budgets. In FY2001, over 93% of the research program was externally supported. A profile of the sponsorship of the Naval Postgraduate School Research Program in FY2001 is provided in Figure 1.

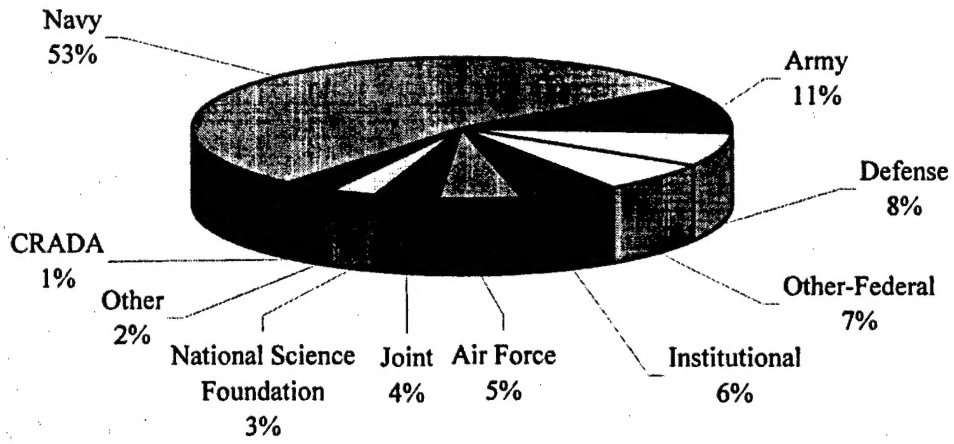


Figure 1. Profile of NPS Research and Sponsored Programs ($52M)

The Office of Naval Research is the largest Navy external sponsor. The Naval Postgraduate School also supports the Systems Commands, Warfare Centers, Navy Labs and other Navy agencies. A profile of external Navy sponsorship for FY2001 is provided in Figure 2.

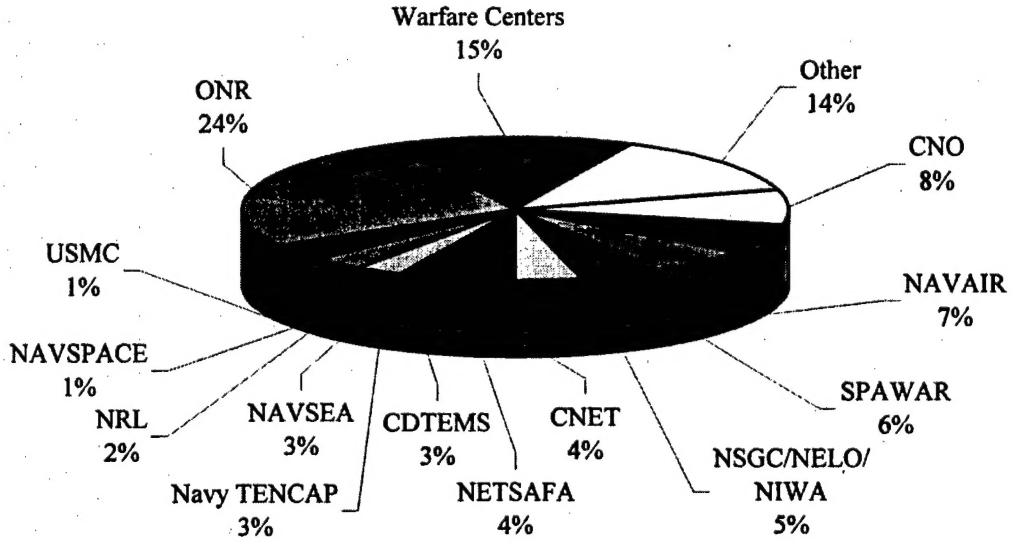


Figure 2. Navy External Sponsors of NPS Research and Sponsored Programs ($29M)

These are both challenging and exciting times at the Naval Postgraduate School and the research program exists to help ensure that we remain unique in our ability to provide education for the warfighter.

DAVID W. NETZER
Associate Provost and Dean of Research

September 2002

INSTITUTE FOR DEFENSE SYSTEMS ENGINEERING AND ANALYSIS (IDSEA)

PHIL DEPOY
DIRECTOR

INSTITUTE FOR DEFENSE SYSTEMS ENGINEERING AND ANALYSIS

OVERVIEW:

On May 28, 2002, the Institute for Defense Systems Engineering and Analysis (IDSEA) was officially renamed the Wayne E. Meyer Institute of Systems Engineering (Meyer Institute).

Research facilitated by the Meyer Institute is designed to develop more extensive interactions and participation with Department of Defense (DOD)/Navy/industry teams conducting significant system-based studies and evaluations. Research within the Meyer Institute is conducted by the faculty and through the selection of topics for student theses.

CURRICULA SERVED:

- Computer Science
  - Modeling and Simulation
- Command, Control, Communications and Intelligence (C4I)
- Operational Logistics
- Total Ship Systems Engineering (TSSE)
- Systems Engineering and Analysis (SEA) (formerly known as Systems Engineering and Integration (SEI))
- Aeronautical Engineering
- Oceanography

RESEARCH THRUSTS:

- Scenario Authoring and Visualization
- Mine Warfare
- Anti-Terrorism/Force Protection
- Data Collection and Analysis for Fleet Battle Experiments
- Joint Warfare
- Concept Modeling
- Future Force Structure
- Evolutionary Computing

RESEARCH CHAIRS:

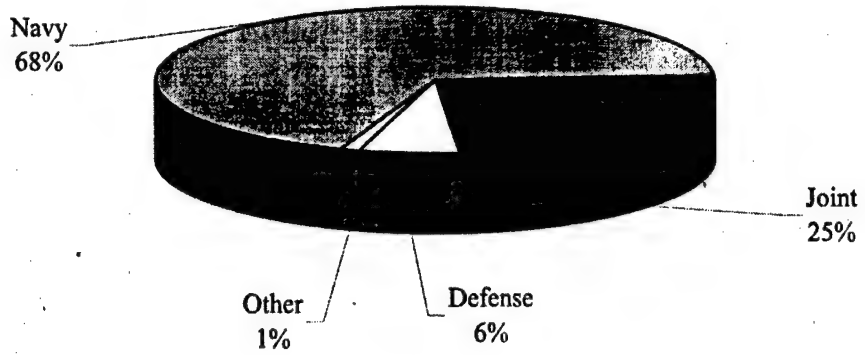
- Expeditionary Warfare

RESEARCH FACILITIES:

- Three Integrated Student Design Labs, consisting of 22 seats, and served by a "War Room" to facilitate team interaction and exchange of ideas.

RESEARCH PROGRAM (Research and Academic)-FY2001:

The Naval Postgraduate School's sponsored program exceeded $49 million in FY2001. Sponsored programs included both research and educational activities funded from an external source. A profile of the sponsored program for the Institute for Defense Systems Engineering and Analysis (IDSEA) is provided below:



Size of Program: $3742K

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MODELING AND SIMULATION TECHNICAL SUPPORT

Curtis L. Blais, Research Associate Professor
Institute for Defense Systems Engineering and Analysis
Sponsor: Space and Naval Warfare Systems Center - San Diego

OBJECTIVE: The Naval Postgraduate School is providing technical consultation for specification and design of amphibious planning models for Marine Corps specific capabilities in the next-generation command staff training system, the Joint Simulation System (JSIMS). JSIMS will be used by the U.S. Marine Corps in joint exercises.

SUMMARY: The Naval Postgraduate School performed the following: 1) Specified user interface requirements for amphibious planning capabilities in USMC JSIMS relating to waterborne and helicopterborne ship-to-shore movements. 2) Reviewed and provided written comments on USMC JSIMS model expositions for Amphibious Operations, to include the Embarkation, Assault, Transition, and Retrograde models. 3) Attended and participated in selected requirements and design review meetings. Advise the SSC-SD USMC JSIMS Program Manager on progress, issues, and concerns with the development.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation

KEYWORDS: Modeling and Simulation, Amphibious Operations, Joint Simulation System (JSIMS)

SCENARIO AUTHORING AND VISUALIZATION, PHASE 2

Curtis L. Blais, Research Associate Professor
Institute for Defense Systems Engineering and Analysis
Sponsor: Defense Modeling and Simulation Office

OBJECTIVE: To perform research and development on browser-based, graphical scenario authoring and exploration tools for ship-to-objective maneuver and other emerging USMC operational employment concepts. The authoring component will enable USMC subject matter experts, working alone or collaboratively as a team, to script a complex scenario in a virtual, extended, littoral battle space.

SUMMARY: Phase 2 work activities included:

- Investigation: Identified additional 3D models to be added to the object palette, including representation of control measures. Investigated representations for built-up areas and expanded warfare areas (e.g., communications and electronic warfare). Researched and identified approaches for embedding intelligent behavior into the scenario objects. Continued investigation of XML-based descriptions of the scenario and possible conversion to scenario input files for large-scale wargaming systems. Investigated architectural changes necessary to convert from DIS to the HLA for multi-user and distributed operation of the Scenario Authoring and Visualization tool (i.e., for collaborative authoring or multiple processor execution of the scenario).
- Design: Modified and developed tools and techniques to enhance authoring software architecture and to expand capabilities in warfare area and object representations.
- Development: Implemented software and tested for the new and modified functional capabilities. Created additional scenarios depicting the interplay of represented land, air, sea, and littoral objects and operations to support testing and demonstration of advanced features of the software. Included study of the interaction of operations with control measures.
- Demonstration: Provided a briefing of software architecture and capabilities at the DMSO Program Review in July 2002.
- Preparing final project software documentation and installation software for delivery to the sponsor and to the Marine Corps.
- Provided project status reporting and performed periodic in-progress reviews with participants and sponsor(s).

NPS faculty performed technical and contractual management, with participation of faculty and students in the engineering activities.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation

KEYWORDS: Modeling, Simulation, Web 3D, Scenario, Generation, Web-Enabled Navy

MINE IMPACT BURIAL MODEL SENSITIVITY STUDY

Peter C. Chu, Professor
Institute for Defense Systems Engineering and Analysis
Sponsor: Naval Oceanographic Office

OBJECTIVE: The Mine Impact Burial Model was developed by the Coastal System Station; subsequent upgrades have been made by the Naval Research Laboratory (NRL). Some of the major input parameters to the model are environment (sedimentation, shear strength, water depth), mine characteristics (shape, center of gravity, weight, and mine deployment parameters), deployment platform (ship, aircraft, submarine), speed of platform, angle of mine upon entering water, rotational velocity at time of deployment and others. The model has undergone limited validation in "R&D" experiments in which most input parameters were carefully measured or monitored. Many of the input parameters will never be known for operational mine deployments; thus, even if the model is accurate using 'perfect' input parameters, it may not be useful if mine impact burial is sensitive to parameters that are seldom known in practice. The purposes are to perform sensitivity tests with the burial model and to investigate the ocean environment of the east Asian marginal seas for mine burial prediction.

SUMMARY: Mine Drop Experiment (MIDEX) was conducted in June 2001 at the NPS swimming pool using 1/20th scale model mines. During the experiment, a three-dimensional hydrodynamic data set of the mine movement in water column was collected. This data was used to evaluate the Navy's Impact Burial Prediction Model (IBPM), which creates a two-dimensional time history of a bottom mine as it falls through air, water, and sediment. The output of the model is the predicted burial depth of the mine in the sediment in meters, as well as height, area, and volume protruding. Model input consists of environmental parameters and mine characteristics, as well as parameters describing the mine's release. The MIDEX data shows that the current IBPM model needs to be improved.

A new research program "Mine Burial Prediction" was initiated at ONR. As a leader for the impact burial team, NPS actively participated the program planning and experiment designing.

DoD TECHNOLOGY AREAS: Battlefield Environments, Environment Effects

KEYWORDS: Mine Burial, Shear Strength, Ocean Survey, Ocean Variability, Ocean Prediction

ASSESSMENT AND RECONSTRUCTION OF NAVY'S MINE IMPACT BURIAL PREDICTION MODEL

Peter C. Chu, Professor
Institute for Defense Systems Engineering and Analysis
Sponsor: Office of Naval Research and Naval Oceanographic Office

OBJECTIVE: The ultimate goals are to substantially improve, quantitatively, the U.S. Navy's mine burial predictive capabilities and to provide a complete data set of mine movement in water phase and mine impact burial for model evaluation. The goals include development of a new mine impact burial model for improving Naval technical decision aids and involvement of NPS students' (U.S. Naval officers) thesis study for enhancing their combat effectiveness.

SUMMARY: Work completed:

- A synchronized data set of ocean environment (including waves, currents, and bottom shear strength) and mine burial depth was established on the base of the Mine Impact Burial Experiment (MIBEX).
- Mine Drop Experiment (MIDEX) was conducted in June 2001 at the NPS swimming pool with 1/20 scale model mines. Around 500 mine drops were completed with different mine parameters and drop conditions. Upon completion of the drop phase, the video from each camera was converted to digital format and a dataset for mine movement in the water column was established.
- Mine test experiment at Carderock was completed.
- The hydrodynamic system depicting the movement of rigid body (such as a mine) in the water column has been established on the base of balance of momentum and moment of momentum.
- Workshop was conducted on ONR Expert System Program on Mine Impact Burial Prediction at NPS on January 10, 2001. The MIBEX dataset was transferred to the ONR Expert System group.

The dynamic system (nine nonlinear equations) for the mine movement has potential impact on the nonlinear dynamics. The hydrodynamics of mine impact in water column can be applied to a general scientific problem of the fluid-rigid body interaction including stability and chaotic motion.

The datasets obtained from three consecutive experiments, MIBEX, MIDEX, and mine testing at Carderock, will impact the scientific and Naval mine warfare communities on the mine movement in the water column.

DoD KEY TECHNOLOGY AREAS: Battlefield Environments, Environment Effects

KEYWORDS: Mine Warfare, Hydrodynamic Theory

CAPTURING THE WEAPON SYSTEM R&D AND ACQUISITION EXPERIENCE FROM THE COLD WAR ERA

Phil E. DePoy, Director
Institute for Defense Systems Engineering and Analysis
Sponsor: Naval Surface Warfare Center - Carderock Division

OBJECTIVE: Discussion of R&D and acquisition experience from the end of WWII until the end of the Cold War with former Naval Laboratory Directors and retired officers who were heavily involved in R&D and acquisition. In addition, a roundtable was held for students and faculty.

SUMMARY: Perhaps at no other period in the Navy's history has the adoption of new technology in the Navy been as pronounced and effective as during the Cold War throughout the fifty or so years following the end of World War II. Key factors in the Navy's ability to make such advances and the circumstances that led to such remarkable achievements were identified:

- Continuity of leadership, funding, and focus.
- Technical competence in Naval officers, the civil service, University labs and industry.
- The existence of discretionary funds in both industry and the government.
- Program managers who were successful and extremely focused, knowledgeable of the technical details of their programs, and were, in effect, their own chief engineers.
- An emphasis on results rather than cost, mutual trust and respect, and a sense of urgency backed up by the courage of convictions.
- The existence of a defined potential enemy created a rather stable funding environment.
- A strong uniformed leadership, with rank aligned with responsibility, for those officers who dealt with the OSD and Congress.
- The in-house laboratories played an important role as honest brokers and keepers of the technical safety net.
- The best leaders, in both industry and government, were those who were rotated through both experiential and educational assignments such that they developed an understanding of the Navy and industry from a corporate sense.

DoD KEY TECHNOLOGY AREAS: Manpower, Personnel and Training, Other (Acquisition)

KEYWORDS: Acquisition, Manpower, Personnel and Training

DATA AND ANALYSIS FOR FLEET BATTLE EXPERIMENT

Shelley P. Gallup, Research Associate Professor
Institute for Defense Systems Engineering and Analysis
Sponsor: Naval Warfare Development Command

OBJECTIVE: Provide data capture, analysis planning and execution, and reporting for Fleet Battle Experiments.

SUMMARY: The Naval Warfare Development Command (NWDC), in cooperation with the numbered Fleets, plans and executes Fleet Battle Experiments (FBEs) through the Maritime Battle Center (MBC). IDSEA/MI develops plans for data collection and analysis design during experiment planning, and then conducts data collection and post-experiment analyses, including:

- Physical Experiment Planning
- Analysis Planning
- Fleet Coordination for Analysis
- Data Capture Planning
- Data Capture
- Analysis
- Quantitative Measures of Effectiveness
- Knowledge Management
- Reporting
- Workshop Planning and Execution
- Modeling and Simulation

DoD KEY TECHNOLOGY AREAS: Command, Control and Communications, Human Systems Interface, Modeling and Simulation

KEYWORDS: Experimentation, Operations Analysis, Knowledge Management, Concept Based Analysis, Network Centric Warfare, Time Critical Strike, Maritime Access, Ballistic Missile Defense

FORCE PROTECTION LIMITED OBJECTIVE EXPERIMENTS

Shelley P. Gallup, Research Associate Professor
Gordon E. Schacher, Professor
Institute for Defense Systems Engineering and Analysis
Sponsor: Office of Naval Research

OBJECTIVE: Plan, execute, and report findings from a series of Limited Objective Experiments (LOEs) directly related to the critical operational issue of Force Protection (FP).

SUMMARY: Force Protection (FP) is an identified Future Navy Capability (FNC), related specifically to the Navy's perceived future access mission. Recent events have underscored the need to understand and implement appropriate capabilities in FP. The LOEs are directed at understanding the means to utilize and enhance organic ship capabilities in a range of conditions, using information technologies.

The proposed Dynamic Port Assessment (DPA) provides timely and useful information directly to a Navy ship prior to visiting a specific port. Improved situational awareness capabilities combined with the DPA must be coordinated with defense in depth, other USN ships in port, innovation in the use of shipboard weapons capabilities, and host nations. This LOE series will result in the development and identification of processes and technologies that permit a coordinated and dynamic capability in FP. The FP LOEs will address the urgent operational requirements for Commander-in-Chief Pacific Fleet; develop a

"Community of Interest" and process to respond to emergent operational needs of Fleet Commanders; and design a "road ahead" for experimentation to address future FP scenarios.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation, Command, Control and Communications, Other (Experimentation, Force Protection, Operations Research)

KEYWORDS: Force Protection, Network Centric Warfare, Knowledge Management

ADAPTIVE ARCHITECTURES FOR COMMAND AND CONTROL

William G. Kemple, Associate Professor
Institute for Defense Systems Engineering and Analysis
Sponsor: Office of Naval Research

OBJECTIVE: To investigate adaptation in joint Command and Control (C2) architecture. To develop theories of C2, i.e., "congruence" of task organization. To use modeling to identify near-optimal organizational decisions for C2 tasks. To test the theories and models in a series of experiments. To support implementation of adaptable C2 architectures.

SUMMARY: Basic research activities related to adaptive command and control occurred in three phases. The first two phases (a concept experiment and scenario pilot testing) were preparatory for Experiment 8, which is the culmination event for FY02. The focus of Experiment 8 (August 2002) is to design two distinct organizations and create two distinct task/resource requirements that would allow the examination of performance and processes in two conditions: 1) where the organization structure was congruent with the task requirements, and 2) where the structure was incongruent. The Concept Experiment 8 conducted in Fall 2001 focused on the preliminary evaluation of two structures (divisional and functional) with a single scenario that emphasized time-critical tasks. The pilot testing conducted in Winter 2002 examined two significantly revised scenarios. The revisions incorporated a series of offensive "mission tasks" that were integrated with the time critical tasks used on Concept 8 experiment. The two scenarios were also designed such that the task requirements would be more readily accomplished by one structure (e.g., divisional) and hypothetically be more challenging for the other structure (e.g., functional).

DoD KEY TECHNOLOGY AREAS: Human Systems Interface

KEYWORDS: Command and Control, Joint Operations, Organizational Experience

ADVANCED COMMAND AND CONTROL (AC2) RESEARCH SUPPORT

William G. Kemple, Associate Professor
Susan Hocevar, Assistant Professor
Institute for Defense Systems Engineering and Analysis
Sponsor: Chief of Naval Operations (N6)

OBJECTIVE: The purpose of this research is to advance our understanding of the implications of network centric operations to command and control. This will be accomplished through an integrated experiment process that links advanced concept seminar-type wargames with simulation-based wargame experiments. OPNAV N6 has identified particular areas of interest to include: Highlight risks and opportunities for C2, explore unintended consequences, identify guiding principles (i.e., rules, models, metrics), clarify and articulate assumptions and relevant uncertainties.

DoD KEY TECHNOLOGY AREAS: Command, Control and Communications, Modeling and Simulation

KEYWORDS: Command and Control, Modeling and Simulation

CENTER FOR DEFENSE TECHNOLOGY AND EDUCATION FOR THE MILITARY SERVICES (CDTEMS)

William G. Kemple, Associate Professor
Sue Hutchins, Research Assistant Professor
Institute for Defense Systems Engineering and Analysis
Sponsor: U.S. Joint Forces Command

OBJECTIVE: To conduct investigations and participate in activities that support joint experimentation and enhance joint capabilities.

SUMMARY: The project team fielded a group of thirteen observer/analysts for Global 2000. The NPS team provided daily and post-game input to the J9 team and administered two surveys. In conjunction with NWDC, a concept for the ETO-to-Actions LOE was developed and conducted. The NPS team served as the lead for training and analysis. The project continued with the follow-on workshop on synchronization and effects assessment.

Planning for the final phases of the Peer-to-Peer (P2P) Wireless LOE was completed. New applications were developed to enable players with COTS PDAs (iPaq) to automatically report their location and to display the locations of all such equipped players on an electronic map.

The NPS team initiated the generation of a web-based 3D representation of the LOE area and events, which can be viewed in collaborative, networked environments. Under other funding, this technology is also being applied to support after-action review in Force Protection LOEs and may be a subject of a future LOE for evaluation of web-based 3D visualization for collaborative mission planning. Agent-based applications were also developed to allow monitoring and repair of the wireless network.

DoD KEY TECHNOLOGY AREAS: Computing and Software

KEYWORDS: Joint Warfare, Joint Experimentation, Knowledge Experimentation, Experimentation Courseware, Concept Modeling, Simulation, Information Warfare and Operations

NAVAL POSTGRADUATE SCHOOL EFFORT TO SUPPORT GLOBAL WARGAME 2001

William G. Kemple, Associate Professor
Sue Hutchins, Research Assistant Professor
Institute for Defense Systems Engineering and Analysis
Sponsor: Office of Naval Research

OBJECTIVE: NPS support for global wargame 2001 will consist of two components. The first component involves direct support to advancing A2C2 research; the second involves providing support to the joint force command J9 effort.

DoD KEY TECHNOLOGY AREAS: Other (Information Technology)

KEYWORDS: Network-Centric Operations, Operational Decision Making, Knowledge Wall

PERFORMANCE AND RISK ASSESSMENT OF FUTURE FORCE STRUCTURES - CALIBRATION EXPERIMENTS

Michael E. Melich, Research Professor
Rodney Johnson, Visiting Professor
Institute for Defense Systems Engineering and Analysis
Sponsor: Defense Advanced Research Project Agency

OBJECTIVE: Develop parameterization of basic radar-based air defense systems in co-evolution with a missile or aircraft based strike system, and estimate the required computing resources as a function of system complexity and level of detail modeling.

SUMMARY: Background of the proposed work was the identification by the investigators of four fields that in combination have the potential to lead to better ways to conceptualize, describe, assess, and integrate force projections and to generate alternative development trajectories: (1) the Living Systems Theory (LST) of James G. Miller; (2) portfolio risk assessment as applied to military R&D; (3) Evolutionary Computation; and (4) Distributed-object modeling. The focus of the work is to exercise the methods on a technically challenging but circumscribed example of a system development problem: the performance/risk analysis of a conceptual future air defense system in coevolution with a conceptual future air strike system. The work ties in with NPS work on bistatic radar systems using satellite-based illuminators.

Proposed tasks include: (1) select and parameterize performance measures for bistatic radar design; (2) perform test runs for bistatic problem; measure resource utilization; (3) perform preliminary LST analysis of development of an air defense system in coevolution with an air strike system-identify risk measures; (4) prepare progress report briefing; (5) estimate resources for applying proposed methods to air defense system development problem; (6) hold meeting of experts in portfolio analysis, risk assessment, and option pricing; (7) prepare final Phase 1 report.

DoD KEY TECHNOLOGY AREAS: Other (Force Planning)

KEYWORDS: Strategic Planning, Technological Forecasting

PERFORMANCE AND RISK ASSESSMENT OF FUTURE FORCE STRUCTURES - COEVOLVED INVESTMENT TRAJECTORIES, POM EXPERIMENTS

Michael E. Melich, Research Professor
Rodney Johnson, Visiting Professor
Institute for Defense Systems Engineering and Analysis
Sponsor: Defense Advanced Research Project Agency

OBJECTIVE: This work continues DARPA funded research begun in April 2000 under the same title. Results achieved in coevolving algorithms for playing the "POM" game will be expanded to include more realistic investment problems.

SUMMARY: The TEMPO Military Planning game is a game of resource allocation used in courses by the Defense Resources Management Institute (DRMI) as a vehicle for introducing concepts of modern defense management. Teams of players compete in building force structures by dividing limited budgets, over a succession of budgeting periods, between categories such as "acquisition" and "operation" of "offensive units" and "defensive units." The rules' apparent simplicity is deceptive: they pose challenging and difficult decision problems. Methods of Evolutionary Computation (EC) have been applied in developing programs for playing games ranging in complexity from tic-tac-toe to checkers. The proposal is to study issues involved in using evolutionary methods to develop computer programs capable of playing the TEMPO game and in extending the results to more realistic and complex problems of resource allocation-that is, to explore the feasibility of using computational power to discover effective resource-allocation strategies. The following issues are to be addressed: (1) scalability; (2) representation of "individuals" (candidate game-players); (3) coevolution (including the ability to generalize from the (symmetric) TEMPO game to non-symmetric situations; (4) introduction of new budget categories. This is a collaborative effort with

Professor Zbigniew Michalewicz (University of North Carolina at Charlotte; NuTech Solutions, Inc.) and others at NuTech.

DoD KEY TECHNOLOGY AREAS: Other (Force Planning)

KEYWORDS: Strategic Planning, Technological Forecasting, Evolutionary Computing

TEST OF DESIGN OF SPARSE OPTICAL ARRAY USING EVOLUTIONARY COMPUTATION

Michael E. Melich, Research Professor
Rodney Johnson, Visiting Professor
Institute for Defense Systems Engineering and Analysis
Sponsor: Naval Research Laboratory

OBJECTIVE: To determine the applicability of evolutionary computing techniques to the design of a partially filled optical aperture intended to be used for imaging.

SUMMARY: "Evolutionary Computation" refers to a family of related approaches to complex computational problems that are finding a wide range of applications to design, optimization, classification, search, and adaptive control. These methods are based on ideas from biology: Darwinian natural selection and survival of the fittest. The context of the proposed work is a larger study of the application of evolutionary and other methods to force structure planning, including the use of evolutionary computation for the conceptual design of weapon system components. In previous work, the investigators had successfully applied evolutionary computation to a problem in phased-array radar antenna design.

The proposed work is a preliminary exploration of the use of evolutionary computation in the design of sparse optical arrays for imaging, e.g. in satellite applications. The work comprises three tasks of which the first is: (1) set up the geometries and representations for the optical aperture; design algorithms and specify "fitness functions." The "fitness function" is the figure of merit to be optimized by a design. Informally, the criterion for an optical array is that a quantity known as the optical transfer function should provide "good coverage" in the domain of spatial frequencies. In the absence of an accepted explicit analytical definition of "good coverage" it was decided to accommodate the use of several plausible "fitness functions" to permit comparison of the designs resulting from each. The second and third tasks are: (2) run the algorithm to generate candidate designs and prepare an annotated briefing of the results; (3) present results to designated representatives of the sponsor.

DoD KEY TECHNOLOGY AREAS: Sensors, Computing and Software

KEYWORDS: Evolutionary Computing, Optical Aperture Design

TECHNOLOGY ASSESSMENT AND ANALYSIS FOR AREA DENIAL

John Osmundson, Associate Professor
Institute for Defense Systems Engineering and Analysis
Sponsor: Naval Warfare Development Command

OBJECTIVE: Analyze technologies that might be available in the 2015 timeframe to be used to deny access of the U.S. Navy to world areas.

SUMMARY: Four phases: 1) identify hostile innovative technologies that have the capability to deny the U.S. Navy access to areas of potential conflict, 2) analyze and assess anti-access technology and compare with intelligence assessments, 3) reconcile Science and Technology plan with anti-access technology and identification of appropriate MOEs and MOPs, and 4) clarify results and address open issues.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Other (Sub-surface, Surface, Air, Space and Cyber Warfare)

KEYWORDS: Area Denial, Red Cell, Innovation Technologies

SUPPORT FOR CONCEPTS TO TECHNOLOGIES FY-01 (CONTECH 01) MINE COUNTERMEASURES (MCM) WARGAME

Clyde L. Scandrett, Associate Professor
John D. Pearson, Chair of Mine Warfare
Institute for Defense Systems Engineering and Analysis
Sponsor: Office of Naval Research

OBJECTIVE: This proposal will provide the FY 01 funding segment for the Office of Naval Research (ONR) sponsored concepts to technologies (CONTECH) wargame series. This wargame series directly supports the ONR future Naval capabilities program in the area of mine countermeasures (MCM).

DoD KEY TECHNOLOGY AREAS: Other (Mine Countermeasures)

KEYWORDS: Future Naval Capabilities, CONTECH Wargames, MCM

INSTITUTE FOR DEFENSE SYSTEMS ENGINEERING AND ANALYSIS (IDSEA)

2001
Faculty Publications and Presentations

JOURNAL PAPERS

Chu, P.C., Lan, J. and Strauhs, H., "A Numerical Simulation of the Japan/East Sea (JES) Seasonal Circulation," *Estuarine and Coastal Modeling, 6*, American Society of Civil Engineering, pp. 94-113, 2000.

Chu, P.C., Lan, J. and Fan, C.W., "Japan/East Sea (JES) Circulation and Thermohaline Structure, Part 1 Climatology," *Journal of Physical Oceanography*, Vol. 31, pp. 244-271, 2001.

Chu, P.C., Lan, J. and Fan, C.W., "Japan/East Sea (JES) Circulation and Thermohaline Structure, Part 2 A Variational P-Vector Method," *Journal of Physical Oceanography*, Vol. 31, pp. 2886-2902, 2001.

Chu, P.C. and Chen, X.S., "Comparison between Wavenumber Truncation and Horizontal Diffusion Methods in Spectral Models," *Monthly Weather Review*, Vol. 129, pp. 152-15, 2001.

Chu, P.C. and Fan, C.W., "A Three-Point Sixth-Order Accuracy Progressive Finite Difference Scheme," *Journal of Atmospheric and Oceanic Technology*, Vol. 18, pp. 1245-1257, 2001.

Chu, P.C., Lu, S.H. and Chen, Y.C., "Evaluation of the Princeton Ocean Model Using the South China Sea Monsoon Experiment (SCSMEX) Data," *Journal of Atmospheric and Oceanic Technology*, Vol. 18, pp. 1521-1539, 2001.

Chu, P.C. and Fan, C.W., "A Low Salinity Cool-Core Cyclonic Eddy Detected Northwest of Luzon During The South China Sea Monsoon Experiment (SCSMEX) in July 1998," *Journal of Oceanography*, Vol. 57, pp. 549-563, 2001.

Chu, P.C., Chen, Y.C. and Lu, S.H., "Evaluation of Haney-Type Surface Thermal Boundary Condition Using a Coupled Atmosphere and Ocean Model," *Advances in Atmospheric Sciences*, Vol. 18, pp. 355-375, 2001.

Liu, Q., Jia, Y., Liu, P., Wang, Q. and Chu, P.C., "Seasonal and Intrasesonal Thermocline Variability in the Central South China Sea," *Geophysical Research Letters*, Vol. 28, pp. 4467-4470, 2001.

CONFERENCE PRESENTATIONS

Bordetsky, A. and Branstetter, T., "Collaborative Technology for Multinational Peace Operations Experimentation," NATO Multinational Experimentation Symposium, Oslo, Norway, September 2001.

Chu, P.C., "Hydrodynamic Theory of Mine Impact Burial," ONR Mine Burial Prediction Science Program Impact Burial Workshop, Crystal City, VA, 14-15 November 2000.

Chu, P.C., "Mine Impact Burial Model and Data Comparison," ONR Expert Systems Modeling Workshop, Monterey, CA, 10 January 2001.

Thate, T., "Identifying Collaborative Tools for Combined Joint Task Force 'Focused Logistics' to Support 'Rapid Decisive Operations'," The Fourth International Conference on Electronic Commerce Research (ICECR-4), Dallas, TX, 8-11 November 2001.

TECHNICAL REPORTS

Buettner, R., "Information Operation/Information Warfare Modeling and Simulation," Naval Postgraduate School Technical Report, NPS-IJWA-01-001.

Chu, P.C., Cintron, C.J., Haeger, S.D., Fox, D.N. and Keenan, R.E., "Yellow Sea Mine Hunting Using the Navy's Cass/Grab Model," Naval Postgraduate School Technical Report, NPS-IJWA-01-016.

Chu, P., Smith, T.B. and Haeger, S.D., "Mine Burial Impact Prediction Experiment," Naval Postgraduate School Technical Report, NPS-IJWA-01-007.

Colon, K., "Development of a Prototype Relational Database System for Managing Fleet Battle Experiment Data," Naval Postgraduate School Technical Report, NPS-IJWA-01-006.

Gaver, D.P. and Jacobs, P.A., "DISC-O-TIC: A Discrete-Time Analytical Meta-Model for Use in Combat Systems that Utilize High Resolution Simulation Models," Naval Postgraduate School Technical Report, NPS-IJWA-01-009.

Gaver, D.P., Jacobs, P.A. and Pilnick, S., "Operations Analysis of Fleet Battle Experiments Using the Battlespace Information War Methodology, Preliminary Report," Naval Postgraduate School Technical Report, NPS-IJWA-01-008.

Harney, R., "The Enemy's Access System - Potential Competitor Exploitation of U.S. Military Vulnerabilities," Naval Postgraduate School Technical Report, NPS-IJWA-01-014.

Irvine, N., "Objective Data from Fleet Battle Experiment Foxtrot, Golf, and Hotel, January 2001," Naval Postgraduate School Technical Report, NPS-IJWA-01-013.

Irvine, N., "Analysis of the Objective Data from Fleet Battle Experiment Hotel, January 2001," Naval Postgraduate School Technical Report, NPS-IJWA-01-012.

Johns, M.D., Pilnick, S. and Hughes, Jr., W.P., "Heterogeneous Salvo Model for the Navy After Next, January 2001," Naval Postgraduate School Technical Report, NPS-IJWA-01-010.

Maruyama, X., "Explosive Detection Technologies for Airline Security," Naval Postgraduate School Technical Report, NPS-IJWA-01-003.

Maule, W.R., Schacher, G., Gallup, S., Marashian, C. and McClain, B., "Ethnographic Qualititative Knowledge Management System Data Classification Schema," Naval Postgraduate School Technical Report, NPS-IJWA-01-002.

Osmundson, J., "Anti-Access System Study," Naval Postgraduate School Technical Report, NPS-IJWA-01-015.

Schacher, G. and Gallup, S., "Complex Experimentation Processes – Fleet Battle Experiment Implementation Summary Report, January 2001," Naval Postgraduate School Technical Report, NPS-IJWA-01-011.

Wirtz, J., "Strategy in the Contemporary World," Naval Postgraduate School Technical Report, NPS-IJWA-01-005.

CONTRIBUTION TO BOOKS

Chu, P.C., "Toward Accurate Coastal Ocean Prediction," *Advances in Mathematical Modeling of Atmosphere and Ocean Dynamics*, Hodnett, P.E., ed., Kluwer Scientific Publishing Co., pp.131-136, 2001.

INSTITUTE FOR INFORMATION SUPERIORITY AND INNOVATION (I2SI)

CYNTHIA IRVINE
DIRECTOR

INSTITUTE FOR INFORMATION SUPERIORITY AND INNOVATION

OVERVIEW:

The Institute for Information Superiority and Innovation was established to be the center for innovative research and education in enabling information technologies, operations, and strategies, with focus on their development and application for national security. The Institute provides a venue for interdisciplinary research in a wide variety of areas related to the capture, processing, display and storage of information in a warfighting environment. Research and educational activities within the Institute are intended to support both immediate and long-term objectives for the effective use of computers and networks within the military.

CURRICULA SERVED:

The Institute for Information Superiority and Innovation does not manage its own curriculum. Instead, students from any curriculum at the Naval Postgraduate School can participate in the Institute's wide range of research and educational programs.

RESEARCH THRUSTS:

- Signals Intelligence
- Electronic Communications Systems
- Electronic Warfare
- Information Warfare
- Information Operations
- Computer and Network Security
- Threat and Risk Analysis and Countermeasures
- System Certification and Accreditation
- Motivations and Operations of Information Threats

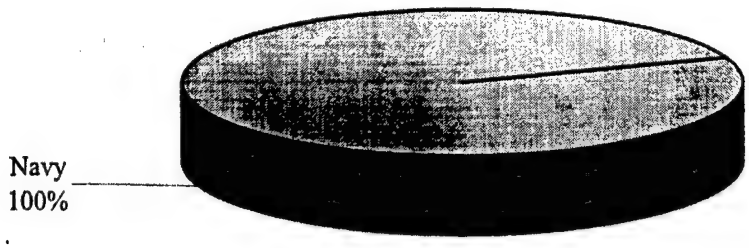
For faculty members investigating these areas, see the research summaries for each faculty member's home department.

RESEARCH CENTERS:

- Cryoptologic Research Center (CRC)
- Center for Information Security (INFOSEC) Studies and Research (CISR)
- Center for the Study of Terrorism and Irregular Warfare

RESEARCH PROGRAM (Research and Academic)-FY2001:

The Naval Postgraduate School's sponsored program exceeded $49 million in FY2001. Sponsored programs included both research and educational activities funded from an external source. A profile of the sponsored program for the Institute for Information Superiority and Innovation (I2SI) is provided below:



Size of Program: $136K

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CDTEMS SUPPORT FOR THE INSTITUTE FOR INFORMATION SUPERIORITY AND INNOVATION

Cynthia E. Irvine, Associate Professor
Institute for Information Superiority and Innovation and Department of Computer Science
Sponsor: Office of Naval Research

OBJECTIVE: The Institute for Information Superiority and Innovation (IISI) has been formed "to be the center for innovative research and education in enabling information technologies, operations, and strategies, with focus on their development and application for national security." The purpose of this support is to provide initiation funds for I2SI activities.

SUMMARY: The NPS Center for Defense Technology and Education for the Military Services (CDTEMS) provided support for the formation of the Institute for Information Superiority and Innovation (IISI) at the Naval Postgraduate School (NPS) in FY01. The mission of the Institute for Information Superiority and Innovation (IISI) is research, application and education in the challenges facing DoN and DoD in the sciences associated with the collection, protection, dissemination, processing, and display of information.

The FY01 CDTEMS funding was used in support of the institute's creation. In particular, the funding was used to support staff to increase the functionality and visibility of the Institute. Domain names were purchased and a web site was created as well as other doucments. The funding permitted planning for first year projects and supported ongoing efforts to ensure adequate resources for the Institute.

DoD KEY TECHNOLOGY AREA: Computing and Software, Command, Control and Communications, Other (Information Operations, Information Warfare)

KEYWORDS: Information Operations, Information Assurance, Computer Security, Network Security, Information Warfare, Command and Control Systems, Cryptologic Systems

INSTITUTE FOR INFORMATION SUPERIORITY AND INNOVATION (I2SI)

2001
Faculty Publications and Presentations

All faculty affiliated with the Institute for Information Innovation and Superiority and Innovation have home departments. See the research summaries for each faculty member's home department for Institute member's presentations and publications.

THE MODELING, VIRTUAL ENVIRONMENTS AND SIMULATION (MOVES) INSTITUTE

MICHAEL ZYDA
DIRECTOR

MODELING, VIRTUAL ENVIRONMENTS, AND SIMULATION

OVERVIEW:

Our mission is research, application and education in the grand challenges of Modeling, Virtual Environments and Simulation (MOVES).

The MOVES Institute operates independently and in collaboration with various U.S. Navy and defense modeling and simulation centers to:

- Carry out basic and applied research
- Analyze continuing modeling, virtual environments and simulation programs
- Create advanced prototypes
- Develop real technologies and applications for the defense community

CURRICULUM SERVED:

- Modeling, Virtual Environments, and Simulation

DEGREE GRANTED:

- Master of Science in Modeling, Virtual Environments and Simulation

FACULTY EXPERTISE:

- Virtual Environments:
  Professor Michael Zyda, Military Instructor CDR Russell Shilling, Lecturer Perry McDowell, Senior Lecturer John Falby, Associate Professor Rudolph Darken, Professor Peter Chu, ResearchAssistant Professor Michael Capps, and Associate Professor Donald Brutzman
- Modeling Simulation:
  Research Associate Professor Wolfgang Baer, Research Associate Curtis Blais, Professor Gordon Bradley, Distinguished Professor Donald Gaver, Research Professor John Hiles, Professor Patricia Jacobs, Associate Professor Thomas Lucas, Associate Professor Neil Rowe, Professor James Taylor, and Associate Professor Xiaoping Yun
- Human Factors:
  Research Assistant Barry Peterson, Professor Robert McGhee, Lecturer Eric Bachmann, Associate Professor Rudolph Darken
- Security:
  Associate Professor Cynthia Irvine
- Communications/Networks:
  Assistant Professor Geoffrey Xie and Professor Nancy Roberts

RESEARCH THRUSTS:

3D VISUAL SIMULATION

- **3D Visual Simulation** - Virtual naval gunfire support. Immersive ship walkthroughs - damage control virtual environments. Littoral zone warfare. Building and Urban Walkthroughs - urban warfare, hostage extraction, operations other than war. Ocean environment tactical visualization. C4I/IW information visualization. Game-engine utilization and handheld visual simulation delivery systems. Synthetic ocean environment simulations.
- **XML/X3D** - Use of Extensible Markup Language (XML) for deploying 3D M&S products over DoD messaging systems, creating interoperable behavior streams, gaining database schema interoperability, and defining ontologies for software agent interactions compatible with deployed C4I and combat control systems.

NETWORKED VIRTUAL ENVIRONMENTS

- **Multicast and Area of Interest Managers** - Software architectures for facilitating the development of large-scale, media-rich, interactive, networked VEs.
- **High Bandwidth Networks** - Experimentation and utilization of next-generation Internet technologies for large-scale, networked virtual environments, and collaborative M&S development and application.
- **Wireless** - Handheld delivery systems.
- **Latency-reduction** - Techniques for predictive modeling in distributed simulations.
- **VE Architectures for Interoperability** - Network software architectures for scalability, composability and dynamic extensibility.
- **Standards for Interoperability** – High Level Architecture; Next Generation RTI; Web-based interoperability. Standards for streamed interactive 3D as an automatically created component for joint message systems. Guiding M&S standards interoperability efforts with the Web3D Consortium, World Wide Web Consortium and MPEG4 Streaming Group.

COMPUTER-GENERATED AUTONOMY

- **Agent-based Simulation** - Computer-generated characters that accurately portray the actions and responses of individual participants in a simulation. Adaptability - computer generated characters that can modify their behavior automatically. Learning - computer generated characters that can modify their behavior over time. Organizational modeling.
- **Story Line Engines** - Content production and simulation prototyping. Technologies for autonomous, real-time story direction and interaction.
- **Human Representations and Models** - Authentic avatars that look, move, and speak like humans.
- **Modeling Human and Organizational Behavior** - Integrative architectures for modeling of individuals, including neural networks; rule-based systems, attention and multitasking phenomena, memory and learning, human decision-making, situation awareness, planning, behavior moderators, modeling of behavior of organizational units, modeling of military operations, and modeling of information warfare.

HUMAN-COMPUTER INTERACTION

- **Training in the Virtual Environment** - Fidelity requirements for wayfinding in the virtual environment. Developing virtual environments for training. Evaluating virtual environments for their utility in training.
- **Intelligent Tutoring Systems** - Developing experts via the use of computer-based virtual environments.
- **Human Factors in Virtual Environments** - Multimodal interfaces, task analysis, spatial orientation and navigation, performance evaluation, interaction techniques, interaction devices, virtual ergonomics, cybersickness, usability engineering, training transfer, human perception.

TECHNOLOGIES FOR IMMERSION

- **Image Generation** - Real-time, computer graphic generation of complex imagery, HDTV, DVD, next generation delivery systems, novel display technologies, handheld and body-worn devices.
- **Tracking** - Technologies for keeping track of human participants in virtual environments.
- **Locomotion** - Technologies that allow participants to walk through virtual environments while experiencing hills, bumps, obstructions, etc.
- **Full Sensory Interfaces** - Technologies for providing a wide range of sensory stimuli: visual, auditory, olfactory, and haptic.
- **Novel Sound Systems** – The generation and delivery for both interactive and recorded media. Spatial sound. Immersive sound and psychoacoustics.

DEFENSE AND ENTERTAINMENT COLLABORATION

- **Technology Transition** - Adapt technologies and capabilities from the entertainment industry.
- **Game-Based Learning** - Distance learning via the use of game technology and development.
- **Internet and Game Delivery Systems** - SimNavy, Army Game Project, SimClinic, SimSecurity.

NEXT GENERATION MODELING

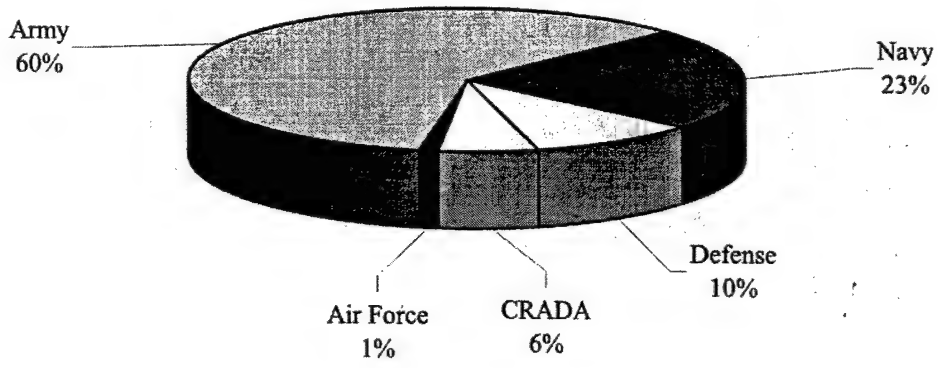
- **Modeling and Simulation** - Dynamic and state space modeling for information warfare and information operations. High-resolution combat models. High-level aggregate models. Network centric warfare. Agent-based simulation. Physically-based modeling to insure physical realism underlies the VR. Theater, tactical and campaign level modeling. Sensor modeling. Architectures for future combat modeling systems.
- **Navy Cyberspace** - Full end-to-end simulation of the ocean environment including subsurface surface, air and space. Oceanographic data sets and models. Tactical databases. Interoperability with live ship tracking message systems. Reusable, in the small or in the large, by fleet assets. Underwater robots. Interoperability with global command and control systems.
- **Current Programs in Combat Modeling** – JSIMS Maritime Battlespace, Naval Simulation System, JSIMS, JWARS, JMASS, OneSAF, HLA, Computer-Generated Forces.

TECHNOLOGY TRANSITION

- Technology transition is part of the MOVES Institute. CRADAs with industry are encouraged as well as the licensing of institute generated intellectual property.

RESEARCH PROGRAM (Research and Academic)-FY2001:

The Naval Postgraduate School's sponsored program exceeded $49 million in FY2001. Sponsored programs included both research and educational activities funded from an external source. A profile of the sponsored program for the Modeling, Virtual Environments and Simulation Institute is provided below:



Size of Program: $3855K

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GENERIC HUB: XML-BASED INFORMATION INTERCHANGE FOR DEFENSE MESSAGING, SHIPBOARD/THEATRE COMMAND AND CONTROL

Donald Brutzman, Associate Professor
The Modeling, Virtual Environments, and Simulation (MOVES) Institute
Sponsor: Naval Undersea Warfare Center - Newport Division

OBJECTIVE: NPS will support and verify IDA conversion of the LC21EDM Data Model to an XML-based schema representation, and further support NUWC efforts to map LC21EDM, DIS and X3D/VRML to shipboard combat control systems. Finally NPS will provide an exemplar amphibious raid operations order in XML along with improved XML-based 3D virtual environment autogeneration. NPS has long been a leader in exploring new technologies for large-scale virtual environments and DoD distributed simulation. Recent results in extensible 3d (X3d) graphics and WEB3D GEOVRML have enabled wide-scale distribution of georeferenced 3D scenes. The NPS DIS-JAVA-VRML working group has further produced a georeferenced 45KM X 55KMM battlespace for Fort Irwin, CA, along with distributed interactive simulation (DIS) networking. NPS work has further shown that XML-based military operation orders can automatically generate matching 3D virtual environments. We proposed to generalize "lessons learned" from these recent successes in support of the generic HUB project, in partnership with NUWC and Institute for Defense Analysis (IDA), for prime sponsor office of Secretary of Defense (OSD).

DoD KEY TECHNOLOFY AREAS: Modeling and Simulation, Command, Control and Communications

KEYWORDS: Shipboard Command Control Systems, Virtual Environments, XML-based Military Operations Orders

OPERATIONS INTEGRATION WORKING GROUP (OIWG) PARTICIPATION

Donald Brutzman, Associate Professor
The Modeling, Virtual Environments, and Simulation (MOVES) Institute
Sponsor: Naval Sea Systems Command

OBJECTIVE: This proposal supports Dr. Brutzman's attendance at monthly meetings of the OIWG at Submarine Development Squadron Twelve, Groton, CT and other facilities. The Navy is conducting the Advanced Tactical Build (ATB) project to infuse advanced tactical control technology into submarine combat subsystems. An ATB consists of tactical decision aids that assist the Commanding Officer in achieving control of the tactical situation and making timely tactical decisions. The Operations Integration Working Group (OIWG) is part of the tactical control development-working group, and evaluates current work and provides peer review of ATB projects.

As part of the various OIWG evaluations, he will provide expert advice on information display technology and designs, particularly with respect to interactive 3D graphics and scientific visualization of sonar sensors. Naval officer students at NPS will also participate in these efforts, through course work and thesis research evaluating the effectiveness of cutting-edge ATB tactical displays and algorighms. NPS will also produce a prototype tactical-visualization training system, illustrating the effective use of 3D graphics for periscope observations and visual contact recognition.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation

KEYWORDS: Advanced Tactical Build, Tactical Decisions

SCENARIO AUTHORING AND VISUALIZATION, PHASE 2

Donald Brutzman, Associate Professor
Curtis L. Blais, Research Associate Professor
The Modeling, Virtual Environments, and Simulation (MOVES) Institute
Sponsor: Defense Modeling and Simulation Office

OBJECTIVE: The purpose of this scenario authoring and visualization project is to perform research and development on browser-bases, graphical scenario authoring and exploration tools for ship to objective maneuver and other emerging USMC operational employment concepts. The authoring component will enable USMC subject-matter experts, working alone or collaboratively as a team, to script a complex scenario in a virtual extended littoral battlespace.

DoD KEY TECHNOLOGY AREAS: Computing and Software

KEYWORDS: Modeling, Simulation, WEB3D, Scario, Generation

STREAMING 3D GRAPHIC USING VRTP FOR DISTRIBUTED SIMULATION

Donald Brutzman, Associate Professor
The Modeling, Virtual Environments, and Simulation (MOVES) Institute
Sponsor: Naval Sea Systems Command

OBJECTIVE: NPS and the George Mason University (GMU) C3I Center networking and simulation laboratory have been leaders in exploring new technologies for DoD distributed simulation. Both groups have worked the areas of virtual environments, network protocol support and multiplatform software tools based on Web browsers and JAVA.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation, Computing and Software

KEYWORDS: Virtual Environments, Network Protocol Support, Multi-platform Software Tools

SOFTWARE FRAMEWORK FOR COMPOSABLE AND SECURE VIRTUAL ENVIRONMENTS

Michael V. Capps, Research Assistant Professor
The Modeling, Virtual Environments and Simulation (MOVES) Institute
Sponsor: Secretary of the Air Force

OBJECTIVE: It is proposed to develop a systems architecture to support composable and extensible immersive virtual environments. This framework will allow development JOF Novel applications in the intelligence domain, both through composition of existing programs and rapid development of new applications. Additionally, this platform will be used to explore new methods for security in virtual world telecollaboration.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation

KEYWORDS: Synthetic Environments, Virtual Environments, Modeling and Simulation

SOFTWARE FRAMEWORK FOR LARGE-SCALE VIRTUAL ENVIRONMENTS SUPPORTING SITUATED COGNITIVE AGENTS

Michael V. Capps, Research Assistant Professor
Rudolph P. Darken, Assistant Professor
Donald Brutzman, Associate Professor
The Modeling, Virtual Environments, and Simulation (MOVES) Institute
Sponsor: Naval Undersea Warfare Center - Newport Division

OBJECTIVE: To develop a large-scale virtual environment framework capable of supporting situated cognitive agents, the framework to allow rapid development of complex VE applications for training and simulation.

SUMMARY: The NPSNET Research Group has designed the architecture of the NPSNET-V system (http://movesinstitute.org/~npsnet/v) to construct a practical working platform for research on infrastructure technology for networked Virtual Environments (VEs). NPSNET-V is the first VE system that offers a tangible demonstration of the benefits of dynamic extensibility and composition in VEs.

NPSNET-V allows the addition of application components during runtime, thereby lending new functionality to a VE. Users can load these components, which consist of Java classes, from disk or the network using standard Java class loading mechanisms. In the same manner, users may discover new types of entities during runtime. The first time a client encounters an entity type, it has only to download its description and create an instance. In this way, simple client applications are dynamically extended to understand new environments and entities as they become available. These capabilities apply to all facets of VE architecture, including communications and even system control protocols.

This is a multi-year project, funded by the CRR and the MOVES Institute. Second year tasks included a series of networked graphical demonstrations and VE architecture based on a minimal kernel.

PUBLICATIONS:

Salles, E., et al, "Security in Run-Time Extensible Virtual Environments," *Proceedings of the 2002 IEEE Workshop on Information Assurance*, United States Military Academy, West Point, NY, June 2002.

THESIS DIRECTED:

Washington, D., "Implementation of a Multi-Agent Simulation for the NPSNET-V Virtual Environment Research Project," Masters Thesis, Naval Postgraduate School, September 2001.

Wathen, S., "Dynamic Scalable Network Area of Interest Management for Virtual Worlds," Masters Thesis, Naval Postgraduate School, September 2001.

Salles, E., "Security in Run-Time Extensible Virtual Environments," Masters Thesis, Naval Postgraduate School (in progress)

DoD KEY TECHNOLOGY AREA: Computing and Software, Modeling and Simulation

KEYWORDS: Virtual Environments, Networking, Simulation, Virtual Reality

NAVIGATION PERFORMANCE ENHANCEMENT IN EXPEDITIONARY WARFARE MISSION PROFILES

Rudolph P. Darken, Associate Professor
The Modeling, Virtual Environments and Simulation (MOVES) Institute
Sponsor: Office of Naval Research

OBJECTIVE: The three focal application areas within the research plan will require delving deeply into basic research issues of (1) cognitive and behavioral modeling, (2) enhancing component spatial skills, and (3) spatial knowledge acquisition. The objective is to investigate the nature of the basic building blocks of these highly aggregated military tasks in order to determine how best to apply technology to specific training needs of modern expeditionary warfare. It is believed necessary to embed this research program in a deep understanding of the problem domain to include extensive field study with sailors and Marines. The specific attributes of the target population are likely to be significantly different than those of the population at large.

The research plan relies heavily on an integrated effort of modeling and empirical experimentation. It should be understood that these are considered to be parallel rather than sequential tasks, beginning with descriptive modeling, possibly including ethnographic techniques. This results in a framework within which experimentation can be structured. Results from the experimentation can then be fed back into the modeling process as construction begins on computational models of navigation. This is an important step that has been struggled with extensively in the past. Learning from the fleet indicates that many navigation tasks are trained via OJT (or on-the-job-training). While it is not foreseen to replace OJT with VE training, VE could be used to enhance OJT methods. This requires an understanding of how these complex processes work, not merely a replication of reasonable expert navigation behavior as might be adequate for CGF (computer generated forces) type application. If a VE training system is to facilitate the training of expert navigation behavior, it needs to understand how experts navigate and be able to teach it. This is the motivation for computation models of human navigation.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation

KEYWORDS: Virtual Environments, Modeling and Simulation, Manpower, Personnel and Training

MANPOWER OPTIMIZATION MODEL FOR MARINE FORCES PACIFIC

John Hiles, Research Professor
The Modeling, Virtual Environments and Simulation (MOVES) Institute
Sponsor: Marine Corps Combat Development Command

OBJECTIVE: Develop a preliminary design and development plan for a manpower optimization model. At the end of the period of work, the design and plan will be delivered.

DoD KEY TECHNOLGY AREAS: Manpower, Personnel and Training

KEYWORDS: Manpower, Modeling, Simulation

AUDIO TECHNOLOGY AND MANAGEMENT IN MODERN NAVY SYSTEMS

CDR Russell Shilling, USN, Military Faculty
The Modeling, Virtual Environments and Simulation (MOVES) Institute
Sponsor: Office of Naval Research

OBJECTIVE: Develop and test advanced audio technology and an interactive audio management user interface for advanced operational Navy workstations and other Navy applications.

DoD KEY TECHNOLOGY AREAS: Human Systems Interface

KEYWORDS: Audio Technology, Interactive Audio Management Users Interface

DEVELOPING AN AUDIOMETRIC MEASURE TO ASSESS LOCALIZATION PERFORMANCE FOR VIRTUAL ENVIRONMENTS AND SPATIALIZED AUDITORY DISPLAYS

CDR Russell Shilling, USN, Military Faculty
The Modeling, Virtual Environments and Simulation (MOVES) Institute
Sponsor: Office of Naval Research

OBJECTIVE: The proposed project is a three-year effort. During the first year, various combinations of audio equipment will be evaluated to determine the appropriateness for use in spatialized audiometry tasks. In addition, appropriate psychophysical tasks will be identified for use in an audiometric test of headphone localization. Perceptual comparisons will be made between off-the-shelf audio equipment and specialized spatial audio equipment to determine whether off-the-shelf components will be adequate for testing localization ability. Companion systems will be created and data collected at Boston University with Barbara Shinn-Cunningham, a leading expert in spatial auditory perception. Aside from sharing equipment and travel expenses for consultation, the collaboration will be at no cost to the government. The second year's effort will use what is learned during the first year to revise the individualized head related transfer functions, and assess the effectiveness of the system. The third year will complete data collection, assemble libraries of highly localizable stimuli and Head Related Transfer Functions (HRTFs), and provide the software and techniques to interested researchers in the audiology and VE community.

DoD KEY TECHNOLOGY AREAS: Human Systems Interface, Computing and Software

KEYWORDS: Spatialized Audiometry, Head Related Transfer Function

ARMY GAME PROJECT

Michael J. Zyda, Professor
John Hiles, Research Professor
Michael V. Capps, Research Assistant Professor
John Falby, Senior Lecturer
The Modeling, Virtual Environments, and Simulation (MOVES) Institute
Sponsor: Office of the Assistant Secretary of the Army – Manpower and Reserve Affairs

OBJECTIVE: The Naval Postgraduate School Modeling, Virtual Environments and Simulation (MOVES) Institute proposes to develop instrumented, networked videogames to improve Army recruiting.

SUMMARY: The U.S. Army has a shortfall in recruiting. There is a potential for improving recruiting through the use of Web-based, instrumented, set of networking videogames or computer games (both of which are hereafter referred to as videogames).

The web-based videogames will: attract people to the Army, provide high fidelity feedback about potential recruits, obtain leads for recruiting, and deliver strategic communications about the Army to the potential recruit.

DoD KEY TECHNOLOGY AREAS: Computing and Software

KEYWORDS: Synthetic Environments, Virtual Environments, Modeling and Simulation, Agent-Based Simulation, Defense and Entertainment

CONTEXT MACHINE - A DEVICE TO DETERMINE CONTEXT FROM SYMBOLIC INPUTS

Michael J. Zyda, Professor
John Hiles, Research Professor
Michael V. Capps, Research Assistant Professor
Perry McDowell, Lecturer
The Modeling, Virtual Environments, and Simulation (MOVES) Institute
Sponsor: Defense Advanced Research Projects Agency

OBJECTIVE: The purpose of the Augmented Cognition Program is to increase the information management capacity of the human-computer warfighting integral by developing and demonstrating quantifiable enhancements to human cognitive ability in diverse, stressful, operational environments of the U.S. warfighter by several orders of magnitude.

SUMMARY: The MOVES Institute at the Naval Postgraduate School is participating in the DARPA Augmented Cognition Program by creating the Context Machine to explore the notion of "context" in a general way, and to study how such a device might improve future warfighting capabilities. The user's current situation, such as their location, their objectives, and the presence of other people and objects, are inputs to the Context Machine. The machine uses the information to determine context. Based upon this context, it determines the best course of action to achieve the user's goals, which is then conveyed to the user. It is imperative that the assistance supplied by the Context Machine be appropriate to the situation, useful, and wanted.

The first step in this research was to identify those situations in which the Context Machine would prove most useful. Those situations are found when the user:

- Cannot understand information in the environment
- Cannot perceive certain information in the environment
- Does not have time to process information in the environment
- Can process the environment, but does not have time to communicate what has been processed.

The second step was to build a software platform for investigation into varying definitions of perception and cognition. A commercial game engine was selected, because of its ready availability from another project, its broad functionality, the ease with which it can be modified, and its reliance on commercial off-the-shelf hardware and software.

A software prototype was successfully constructed in which the Context Machine aids an infantryman on a clandestine reconnaissance mission. This demonstration was presented to the DARPA sponsor, as well as to numerous distinguished visitors to the Naval Postgraduate School.

As a result of these efforts, the project has been funded for an additional three years.

PUBLICATIONS:

McDowell, P., "A Taxonomy of Context Based Computing," (Paper in progress)

PRESENTATIONS:

Zyda, M. J., "Interest Management," Workshop on Perceptive User Interfaces, Orlando, Florida, 15 November 2001.

THESIS DIRECTED:

McDowell, P., "The Context Machine: A Device to Determine User's Context from Incomplete Data," Ph.D. Dissertation, Naval Postgraduate School, (in progress)

DoD KEY TECHNOLOGY AREAS: Battlespace Environments, Command, Control, and Communications, Computing and Software, Human Systems Interface, Modeling and Simulation

KEYWORDS: Virtual Reality, Augmented Cognition, Perception Modeling, Augmented Reality

ESTABLISHMENT OF AN ARMY VIDEO GAME

Michael J. Zyda, Professor
John Hiles, Research Professor
Michael V. Capps, Research Assistant Professor
The Modeling, Virtual Environments and Simulation (MOVES) Institute
Sponsor: Office of the Assistant Secretary of the Army for Manpower and Reserve Affairs

OBJECTIVE: To design, develop, test, install, maintain, and operate instrumented and networked interactive Army video games, for use on the Microsoft Windows system.

SUMMARY: 2001 was the second year of this five-year project. The initial software releases are planned for 2002, and therefore, this year was spent in research and development. Demonstrations of software progress were given to sponsor representatives at all levels, up to and including the Secretary of the Army.

The staff for this project consists of nearly 25 MOVES faculty, staff, and full-time on-site contractors. Student thesis research provides important input as well, and our graphics engine technology has provided a stable and full-featured platform for experimentation. Thesis topics are quite varied, which demonstrates the complex nature of this project; research areas include dynamic story creation, agent-based intelligence for infantry simulation, rendering algorithms for terrain geometry, and rotary-winged vehicle physics.

PUBLICATIONS:

Capps, M., McDowell, P., and Zyda, M., "A Future for Entertainment-Defense Research Collaboration," *IEEE Computer Graphics and Applications*, January/February 2001.

Capps, et al., "Gaming Techniques for Building Compelling Virtual Worlds," SIGGRAPH 2001, Los Angeles, CA, July 2001.

THESES DIRECTED:

Back, D., "Agent-Based Soldier Behavior in 3D Game Environments," Masters Thesis, Naval Postgraduate School, (in progress).

Buhl, C., "Defense-Entertainment Collaboration," Masters Thesis, Naval Postgraduate School, (in progress).

Osborne, B., "An Agent-Based Architecture for Guiding Interactive Stories," Ph.D. Dissertation, Naval Postgraduate School, (in progress).

Spears, V., "Terrain Level of Detail in First Person, Ground Perspective Simulation," Masters Thesis, Naval Postgraduate School, (in progress).

Perkins, K., "Implementing Realistic Helicopter Physics/Artificial Intelligence in 3D Game Environments," Masters Thesis, Naval Postgraduate School, (in progress).

EXPLAINATIONS USED IN TUTORING

Michael J. Zyda, Professor
Rudolph P. Darken, Associate Professor
Barry Peterson, Research Assistant
The Modeling, Virtual Environments, and Simulation (MOVES) Institute
Sponsor: Naval Undersea Warfare Center and Defense Advanced Research Projects Agency

OBJECTIVE: Existing intelligent tutoring system (ITS) provide at best rudimentary explanations of the desired actions overall task performance. Such explanations play a key role in real interactions between a human student and tutor. Therefore, one potential way to improve the quality of training provided by ITS is

to incorporate explanations into the feedback that the virtual tutor provides that are based on the types of explanations that real tutors would give in that same scenario.

SUMMARY: To achieve that end, a Teo-Phase approach is proposed. First, field studies will be conducted to describe the behavior and role of explanation in real-world mentoring relationships. Second, this description will categorize and encode into a form amenable to a cognitive architecture

DoD KEY TECHNOLOGY AREAS: Computing and Software

KEYWORDS: Computing, Intelligent Tutoring Systems, Cognition, Explanation

INTERNAL MOTION TRACKING TECHNOLOGY FOR INSERTING HUMANS INTO A NETWORKED SYNTHETIC ENVIRONMENT

Michael J. Zyda, Professor
Xiaoping Yun, Associate Professor
Barry Peterson, Research Assistant
The Modeling, Virtual Environments, and Simulation (MOVES) Institute
Sponsor: U.S. Army Research Office

OBJECTIVE: This proposal requests continued support to develop an internal track body suit that is able to track the entire human body and to integrate the tracking data into a networked virtual environment. This body suit would require the construction of fifteen of the MARG sensors prototyped in the current effort.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Human Systems Interface

KEYWORDS: Networked Synthetic Environment

SELF-LEARNING AUTONOMOUS AGENTS FOR DISTRIBUTED SIMULATORS

Michael J. Zyda, Professor
Michael Van Putte, Ph.D. Student
Brian Osborn, Student
The Modeling, Virtual Environments and Simulation (MOVES) Institute
Sponsor: Defense Modeling and Simulation Office

OBJECTIVE: This research proposes to develop a prototype self-learning multi-agent architecture adaptable to military situations. There is a potential for improving simulation realism, fidelity and overall effectiveness by developing a multi-agent based simulatios, populated with self-learning autonomous agents. This research proposes to develop a prototype self-learning multi-agent architecture adaptable to military simulations. Large scale distributed simulations play a vital role in every military planning. From the assessment of military hardware and evaluation of combat doctrine, to identifying computer security vulnerabilities and conducting rehearsal training, computer simulation is a fundamental resource for decision makers.

Self-learning agents in distributed simulations would provide the ability to explore the effects of a changing environment and potential impact of future technologies in military operations. Self-learning agents would themselves be able to explore and develop new procedures and identify vulnerabilities in response to changing capabilities and threats, moral and political constraints, and unit skill levels.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation

KEYWORDS: Modeling and Simulation, Agent-based Simulation, Self-learning Autonomous Agent

THE MODELING, VIRTUAL ENVIRONMENTS AND SIMULATION (MOVES) INSTITUTE

2001
Faculty Publications
and Presentations

JOURNAL PAPERS

Capps, M., McDowell, P., and Zyda, M., "A Future for Entertainment-Defense Research Collaboration," *IEEE Computer Graphics and Applications*, January/February 2001.

Morse, K. and Zyda, M., "Multicast Grouping for Data Distribution Management," *SIMPRA - Journal of Simulation Practice and Theory*, Fall 2001.

Yun, X.P., Bachmann, E.R., Suat, A., Akyol, K. and McGhee, R.B., "An Inertial Navigation System for Small Autonomous Underwater Vehicles," *Advanced Robotics*, Vol. 15, No. 5, pp. 521–532, October 2001.

CONFERENCE PAPERS

Bachmann, E., McGhee, R., Yun, X. and Zyda, M., "Inertial and Magnetic Posture Tracking for Inserting Humans Into Networked Virtual Environments," *Proceedings of ACM Symposium on Virtual Reality Software & Technology (VRST 2001)*, Banff, Alberta, Canada, pp. 9-16, 15-17 November 2001.

Darken, R., Kempster, K. and Peterson, B., "Effects of Streaming Video Quality of Service on Spatial Comprehension in a Reconnaissance Task," *Proceedings of I/ITSEC*, Orlando, FL, 2001.

Marins, J., Yun, X., Bachmann, E., McGhee, R. and Zyda, M., "An Extended Kalman Filter for Quaternion-Based Orientation Estimation Using MARG Sensors," *Proceedings of the 2001 IEEE/RSJ International Conference on Intelligent Robots and Systems*, Maui, HI, pp. 2003-2011, 29 October-3 November 2001.

Peterson, B., Boswell, J. and Darken, R., "Collaborative Navigation in Real and Virtual Environments," *Proceedings of I/ITSEC*, Orlando, FL, 2001.

CONFERENCE PRESENTATIONS

Capps, et al., "Gaming Techniques for Building Compelling Virtual Worlds," SIGGRAPH 2001, Los Angeles, CA, July 2001.

Peterson, B., Boswell, J. and Darken, R., "Software Intensive System Integration," Monterey Workshop 2001, Monterey, CA, 19-21 June 2001.

Zyda, M., "The Future of Modeling, Virtual Environments and Simulation," IITSEC 2001, Orlando, FL, 29 November 2001.

Zyda, M., "The Future of Interactive Networked Entertainment," IITSEC 2001, Orlando, FL, 26 November 2001.

Zyda, M., "'Interest Management," Perceptive User Interfaces Workshop, Orlando, FL, 15 November 2001.

Zyda, M., "Inventing Your Own Academic Degree and Research Institute," University of California Research Conference on Herding Cats, Moving Cemeteries, and Hauling Academic Trunks - Managing Change in Higher Education, UCLA Faculty Center, Los Angeles, CA, 19 October 2001.

Zyda, M., Panel on "The Future of Interactive Networked Entertainment," VSMM Conference, Berkeley, CA, 27 October 2001.

Zyda, M., "The MOVES Institute," Summer Computer Simulation Conference, Orlando, FL, 16-18 July 2001.

Zyda, M., "The MOVES Institute," MOVES Institute Open House, Naval Postgraduate School, Monterey, CA, 28 August 2001.

Zyda, M., "The Future of Modeling, Virtual Environments and Simulation," Summer Computer Simulation Conference, Orlando, FL, 16-18 July 2001.

Zyda, M., "Trends in Virtuality - Processors, 3D, Internet & Application," CIO Connect via Celebrity Speakers International, London, 12 June 2001.

TECHNICAL REPORTS

McGhee, R., Bachmann, E., Yun, X. and Zyda, M., *An Investigation of Alternative Algorithms for Singularity-free Estimation of Rigid Body Orientation from Earth Gravity and Magnetic Field Measurements*, Naval Postgraduate School Technical Report, NPS-MV-02-001, October 2001.

McGhee, R., Bachmann, E., Yun, X. and Zyda, M., *Real-Time Tracking and Display of Human Limb Segment Motions Using Sourceless Sensors and a Quaternion-Based Filtering Algorithm – Part I: Theory*, Naval Postgraduate School Technical Report, NPS-MV-01-001, November 2000.

PATENTS

Bachmann, E., McGhee, R., McKinney, D., Yun, X. and Zyda, M., "Method and Apparatus for Motion Tracking of an Articulated Rigid Body," Provisional Patent filed October 1999, final patent filed 30 October 2001.

Institute for Defense Systems Engineering and Analysis (IDSEA)

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The Modeling, Virtual Environments, and Simulation (MOVES) Institute

Thesis Abstracts

MODELING BLUETOOTH RADIO TECHNOLOGY SIMULATION USING MULTI-AGENT BASED SYSTEM AND GENETIC ALGORITHM DESIGN PARADIGM

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This thesis uses Multi-Agent systems (MAS), and Genetic Algorithm (GA) techniques to develop a BluetoothTM radio system simulation that is called "Wireless World". Typically, wireless world is a simple two-dimensional (2D) toy model of BluetoothTM Technology implemented in the Java programming language version 1.2.1 and Borland jbuilder3 university edition editor environment. In addition, the wireless model is designed for outdoor environment for the six different weather conditions. And in the environment, there may be situated three types of interference systems. Within these systems, the IEEE 802.11b WLAN, an alternative to the BT, is implemented as interference in the simulation environment. The goal of the wireless world simulation is to explore the performance limitations and restrictions on the basis of the current BluetoothTM technology specifications. The wireless world simulation will hopefully help BluetoothTM system designers and decision-makers in gaining insight into the system performance analysis and enable them to make more informed decisions in the future.

DoD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Agents, Multi-Agent System, MAS, Agent-based Simulation, Adaptive Agents, Autonomous Agents, Relationship, Game Theory, Genetic Algorithm, Distributed Artificial Intelligence, DAI, Mobile Agent, Bluetooth, IEEE 802.11b, WLAN

DEVELOPING ARTICULATED HUMAN MODELS FROM LASER SCAN DATA FOR USE AS AVATARS IN REAL-TIME NETWORKED VIRTUAL ENVIRONMENTS

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With the continuing gain in computing power, bandwidth, and Internet popularity, there is a growing interest in Internet communities. To participate in these communities, people need virtual representations of their bodies, called avatars. Creation and rendering of realistic personalized avatars for use as virtual body representations is often too complex for real-time applications such as networked virtual environments (VE). Virtual Environment (VE) designers have had to settle for unbelievable, simplistic avatars and constrain avatar motion to a few discrete positions.

The approach taken in this thesis is to use a full-body laser-scanning process to capture human body surface anatomical information accurate to the scale of millimeters. Using this 3D data, virtual representations of the original human model can be simplified, constructed and placed in a networked virtual environment.

The result of this work is to provide photo realistic avatars that are efficiently rendered in real-time networked virtual environments. The avatar is built in the Virtual Reality Modeling Language (VRML). Avatar motion can be controlled either with scripted behaviors using the H-Anim specification or via wireless body tracking sensors developed at the Naval Postgraduate School. Live 3D visualization of animated humanoids is viewed in freely available web browsers.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation

KEYWORDS: Avatar, Real-Time Networked Environments, Virtual Reality Modeling Language

OPERATIONAL-LEVEL NAVAL PLANNING USING AGENT-BASED SIMULATION

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This thesis uses agent-based modeling techniques to develop a simulation of the operational-level naval planning process. The simulation serves as an initial exploratory laboratory for analyzing the consequences of the force allocation, force deployment, and force movement decisions made by operational-level naval commanders during times of conflict or crisis. This model will hopefully help decision-makers in gaining insight into the naval planning process and enable them to make more informed decisions in the future.
The agents in the model represent the opponent operational-level naval commanders. These agents perform force allocation, force deployment, and force movement tasks based on their perceived environment, attributes, and movement personalities. There are seven naval platform types represented in the model by default, but any type of naval platform can be added to the simulation. An integrated graphical user interface enables the user to instantiate agent and platform attributes, set simulation parameters, and analyze statistical output.

The resulting model demonstrates the ability of the agent-based modeling to capture many dynamic aspects of the operational-level naval planning process. It establishes an initial simulation tool to further explore the operational-level naval planning process.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation, Other (Naval Planning)

KEYWORDS: Multi-Agent System, Agent-Based Modeling, Adaptive Behavior

WEB-ENABLED DOCTRINE: THE EVOLUTION OF A DYNAMIC DOCTRINE DEVELOPMENT PROCESS IN THE UNITED STATES NAVY

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The Navy envisions a dynamic development process for doctrine that produces accessible, timely, and relevant doctrine for the Fleet. The Navy Warfare Development Command (NWDC) in Newport, RI, recently has implemented information technology tools in the doctrine development process, creating the concept of Web-enabled Doctrine. This thesis analyzes Web-enabled Doctrine as the next step forward in the evolution of a dynamic doctrine process. This thesis presents an historical study of doctrine in the U.S. Navy, a description of the Navy's doctrine development process over the past three decades, and an evalution of the current system with respect to the characteristics of a dynamic process. Data on the current process and Web initiatives were gathered through interviews with current and former NWDC staff members.

The results indicate that NWDC has increased the level of responsiveness in the process, thus improving the relevance and timeliness of doctrine. Recommendations are made for increased accessibility to the system and the migration towards emerging commercial Web standards (XML).

DoD KEY TECHNOLOGY AREA: Command, Control, and Communication

KEYWORDS: Web-enabled Doctrine, Doctrine Development, Naval Doctrine History, Dynamic Doctrine

ANALYZING PERSONNEL RETENTION UTILIZING MULTI-AGENT SYSTEMS

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As we enter the 21st Century, the Department of Defense finds itself facing a significant personnel crisis. Despite a thirty percent reduction in manpower needs, the military is continually failing to meet its retention requirements.

There are numerous factors that are causing this problem, to include the booming U.S. economy, the highest military deployment rates in our history, and the widespread use of the Internet. The result is that our service members have more non-military career options than ever before, and too many are choosing them. The problem appears to be getting worse as recent surveys indicate that over 50 percent of the enlisted force, and over 33 percent of the officer force intend to leave the military at their next opportunity.

The drastic change in retention behaviors did not occur overnight, yet the military failed to react quickly to the change. The reason for this is that strength projections are calculated using linear models, which are based upon historical data; these programs are incapable of warning about non-linear behaviors. If the military had used supplemental non-linear models, it most likely would have been able to react sooner.

This thesis, therefore, provides the Military Personnel Retention Simulator (MPRS), a model for exploring non-linear retention behaviors in an ever-changing environment. The model utilizes modern object-oriented programming, high-speed processors, and multi-agent system concepts in order to provide an unsituated environment which users can manipulate in order to observe potential retention behaviors. The model is exploratory in nature, and is therefore not predictive. Users are therefore urged to utilize the MPRS in support of the decisions that they make, and not as the basis for such decisions.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Modeling, Simulation, Retention, Multi-Agent Systems, Complex Adaptive Systems, Strength Management, Manpower Forecasting

USING INFORMATION TECHNOLOGY IN THE NAVY LESSONS LEARNED SYSTEM TO IMPROVE ORGANIZATIONAL LEARNING

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Organizations are becoming increasingly aware that learning can be a source of competitive advantage. The United States Navy is not immune to this realization and has established the Navy Lessons Learned System (NLLS) as the singular Navy program for the collection, validation, and distribution of unit feedback. NLLS provides naval personnel a means to share observations, document deficiencies, convey solutions, and innovate tactics, techniques, or procedures (TTP). The purpose of this thesis is to examine the various factors that influence organizational learning, such as structure, environment, and culture, and to examine how information technology can be used to support or enhance organizational learning in the Navy. The research concludes that NLLS has improved organizational learning but has not attained as widespread use as is possible. Recommendations are provided to improve the program as well as increase NLLS exposure to the fleet and to the potential users of the system.

DoD KEY TECHNOLOGY AREA: Manpower, Personnel, and Training

KEYWORDS: Information Systems, Organizational Learning, Navy Lessons Learned System, Information Technology

JAVA-BASED IMPLEMENTATION OF MONTEREY-MIAMI PARABOLIC EQUATION (MMPE) MODEL WITH ENHANCED VISUALIZATION AND IMPROVED METHOD OF ENVIRONMENTAL DEFINITION

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The Monterey-Miami Parabolic Equation (MMPE) Model is a full-wave underwater acoustic propagation model that utilizes the split-step Fourier marching algorithm. Previously the MMPE model was implemented in Fortran language and ran with a simple command line interface either in a Unix or DOS command window. After the Fortran code was run, the resulting binary data output file was post-processed using Matlab routines to extract specific field data and present the results in graphical form. This approach requires the user to have installed both Matlab and Fortran compilers. The MMPE model and associated acoustic processing tools are now rewritten in the object-oriented language Java. This new version of the MMPE model built within a Windows framework is called WinMMPE. Integrating the model, the post-processing calculations and the graphics generation together with a graphic user interface has produced a more attractive tool for users. A user-friendly, efficient, and accurate full-wave acoustic propagation model with enhanced visualization can make it easier to assess the spatial transmission loss in underwater acoustic environment.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Underwater Acoustic Propagation, Acoustic Modeling, Java, Parabolic Equation, MMPE, Winmmpe, VRML, 3D, Sonar Visualization

ANALYSIS OF MAINTENANCE RECORDS TO SUPPORT PREDICTION OF MAINTENANCE REQUIREMENTS IN THE GERMAN ARMY

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Today the German Armed Forces are faced with a broad, varied and graduated range of tasks including missions outside Germany. A major challenge in planning the force structure for missions like the one in Kosovo is to predict the required maintenance capacities. This thesis conducts an exploratory data analysis of maintenance records of the German Army, using the wheeled reconnaissance tank "Luchs" as an example. The question under investigation is whether or not data from the maintenance records can be used to support a future "maintenance prediction tool." It is shown that repairtime distributions extracted from the data can be used to model the repair process in a simulation. The Weibull distribution family, which is commonly used in reliability applications, proved flexible enough to simulate repairtimes and workorder supply times. Implementing these results in a simulation of the repair process will improve the accuracy and quality of the simulation output. In addition, this thesis discusses data quality issues and makes design suggestions for a new maintenance organization software. Data problems can be minimized if the problems identified in this study are aggressively attacked during the design and implementation phases of the new software.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation, Other (Logistics)

KEYWORDS: Maintenance, Repairtime Distribution, Data Quality, German Army

DESIGNING REALISTIC HUMAN BEHAVIOR INTO MULTI-AGENT SYSTEMS

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As Multi-agent systems advance toward moving virtual humans such as modeled infantry soldiers around a virtual environment for modeling and simulation purposes, an important factor to be considered is how the agent internalizes and reacts to its environment. One method to simulate this sensory perception and the construction of generalized internal knowledge is the symbolic reactive agent architecture. This architecture utilizes symbolic constructive agents to internalize and symbolically represent the outside environment within the agent and reactive agents to decide what course of action will be taken next based on this internal environment. This type of architecture also lends itself well to putting variability and non-homogeneity into different agents by controlling the level of hindrance or interference that the agent utilizes when constructing this inner environment. A simple path finding task was used to determine the overall utility of this architecture with respect to truly representing human performance in cognitive tasks. Humans as well as different simulated agents were put through the same task in their respective environment and their results were compared. A concept called the bracketing heuristic was also utilized to determine whether the model may translate well to general path-finding tasks.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation

KEYWORDS: Multi-Agent Systems, Virtual Humans

3D VISUALIZATION OF TACTICAL COMMUNICATIONS FOR PLANNING AND OPERATIONS USING VIRTUAL REALITY MODELING LANGUAGE (VRML) AND EXTENSIBLE 3D (X3D)

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The military is increasingly reliant on communication networks for day-to-day tasks as well as large-scale military operations. Tactical communications networks are growing progressively more complex as the amount of information required on the battlefield increases. Communication planners require more advanced tools to perform and manage signal-planning activities. This work examines the use of 3D visualizations to assist in tactical signal planning. These visualizations are developed using Virtual Reality Modeling Language (VRML), Extensible 3D (X3D) graphics, and Distributed Information Simulation (DIS) for network connectivity.

These visualizations and the connectivity provide signal planners the ability to generate 3D scenarios quickly identifying problems such as frequency interference, connectivity problems, and marginal-coverage areas. Network connectivity also provides a collaborative planning environment for geographically dispersed units.

The NATO Global Hub Land C2 Information Exchange Data Model (LC2IEDM) is a semantic model designed for information passing between systems. This work also examines LC2IEDM for its ability to represent tactical communication plans and facilitate the autogeneration of 3D scenarios.

DoD KEY TECHNOLOGY AREAS: Command, Control, Communications, Modeling and Simulation

KEYWORDS: 3D Visualizations, Virtual Reality Modeling Language (VRML), Extensible 3D (X3D), Tactical Communications, Communications Planning, NATO Global Hub, Land C2 Information Exchange Data Model (LC2IEDM)

EXPERIMENTATION METHODOLOGY FOR EVALUATING OPERATIONAL INFOCON IMPLEMENTATIONS

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Information Operation Condition (INFOCON) implementations and specifically the impact these implementations can have on warfighting command and control processes are not yet widely understood or appreciated by the majority of the operating forces. INFOCON actions are designed to heighten or reduce defensive posture uniformly, to defend against computer network attacks, and to mitigate sustained damage to the DoD infrastructure. Experimentation is required to explore the effects on certain command and control processes under various INFOCON conditions. This thesis explored requirements for conducting these INFOCON experiments and resulted in the development of an INFOCON experimental design methodology that can be used as a framework for designing and conducting INFOCON experiments in the field. INFOCON experimentation will provide insights and a better understanding of the effects that these implementations will have on the ability of a commander to command and control his or her forces.

DoD KEY TECHNOLOGY AREA: Command, Control and Communications

KEYWORDS: Information Operation Condition (INFOCON), Experimentation, Network Centric Warfare

MODELING CONVENTIONAL LAND COMBAT IN A MULTI-AGENT SYSTEM USING GENERALIZATION OF THE DIFFERENT COMBAT ENTITIES AND COMBAT OPERATIONS

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There are inherent similarities between the numerous ground combat entities and the numerous ground combat operations. In combat entities there exist common characteristics such as the ability to move, shoot, communicate and more. The levels that each entity is able to operate for these characteristics differentiate it from the others. For combat operations, a common characteristic is that all operations have a starting point, objective point and an endpoint. The different operations take on unique properties based on where these points are located, actions enroute to points and what entities do at these points.

The generalized concepts in combat entities and combat operations provide a framework that can assist developers and users to model the majority of combat situations with a single simulation. This thesis uses three different Multi-Agent System (MAS) combat models to illustrate the generalization framework. Of the three "test" models used, two existed previously and one was developed. The two existing models are Map Aware Non-uniform Automata (MANA), developed for the New Zealand Army and Defense Force, and Archimedes developed by Least Squares Software LLC. The model (GENAgent) was developed based

on the redesign of GIAgent, developed by Captain Joel Pawloski, USA, as a thesis at the Naval Postgraduate School.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation

KEYWORDS: Multi-Agent System, Conventional Land Combat, GENAgent, GIAgent

SCENARIO AUTHORING AND VISUALIZATION FOR ADVANCED GRAPHICAL ENVIRONMENTS (SAVAGE)

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Today's planning and modeling systems use two-dimensional (2D) representations of the three-dimensional (3D) battlespace. This presents a challenge for planners, commanders, and troops to understand the true nature of the battlespace. This thesis shows how 3D visualization can give both operation planners and executors a better understanding of the battlespace that can augment today's 2D systems. Automatic creation of a 3D model for an amphibious operation allows the planner to view an operation order as a whole, from different perspectives. Recommended changes can be made and their effects immediately known. Warfighters can use the same tools for mission preparation and review.

The United States and NATO nations use the Land C2 Information Exchange Data Model (LC2IEDM), formally known as the Generic Hub, as a common method for exchanging data between independent systems. As part of the Scenario Authoring and Visualization for Advanced Graphical Environments (SAVAGE) project, this research presents an integrated Web access and 3D visualization strategy for Department of Defense (DOD) tactical messaging and operation orders using the Generic Hub data model and the Extensible Markup Language (XML). A number of alternative yet consistent ways to represent an amphibious operation scenario demonstrate the power, flexibility and scalability of the SAVAGE approach.

EMERGENT LEADERSHIP ON COLLABORATIVE TASKS IN DISTRIBUTED VIRTUAL ENVIRONMENTS

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Several Department of Defense agencies are currently investigating the use of distributed collaborative virtual environments (CVE) for the training of small dismounted infantry teams. If these systems are to be successful, they will have to do more than simply allow the team members to execute a task. In addition to assuring that essential training in the CVE transfers to the real task, it must be ensured that aspects of team organization also transfer. In particular, this thesis investigates whether or not predicted emergent leadership, as measured by standardized personality tests, holds within a CVE or if aspects of the interface interfere.

For a given "real-world" task domain a leader can be predicted based on personality traits of the individuals within the group. The interface utilized with a CVE may adversely affect these traits. In other words, predictive measures of leadership in the real world may not hold in a CVE.

The study reported here will use this predictability to identify the expected emergent leader within a group and determine how the CVE interface affects the ability of the predicted individual to emerge as the leader. It is theorized that the limitations of CVE interfaces (field of view, realism, etc.) will negatively impact the transfer of leadership personality traits into the virtual environment, but not to a degree that the

limitation cannot be overcome. These limitations may impact the group dynamics and the emergent leader may not necessarily be the predicted leader by personality traits.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation

KEYWORDS: Virtual Environments, Collaborative Virtual Environments, CVE

MODELING TACTICAL LEVEL COMBAT USING A MULTI-AGENT SYSTEM DESIGN PARADIGM (GI AGENT)

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In the past 60 years the Army has undergone a major reorganization eight times at the divisional level and numerous more times at unit levels below the division. Each time the Army reorganized it's divisions a major testing program was involved. But when a change in organization is done at unit levels below division often very little attention is paid to how the change will affect the unit. When this happens, unit leaders are forced to undertake one of the most difficult jobs in today's military incorporating new equipment into a unit or reorganizing a unit without an understanding of how the changes will affect the unit.

The Military modeling and simulation community has attempted to fill this need but the current set of single entity simulations are limited in their ability to replicate dynamic complex behavior. This thesis is attempting to create a Multi-Agent Simulation that will allow analysts and leaders to gain an understanding of the tactical employment affects of changing the organization of a company level infantry unit.

GI Agent is a simulation tool allowing the analyst and leader to experiment with the complex relationship between maneuver and unit organization without putting the unit in the field. Combining agent based artificial intelligence techniques with artificial intelligence research from the computer gaming industry, GI Agent creates a new paradigm for combat simulation.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Modeling and Simulation

KEYWORDS: Multi-Agent System, MAS, Combat Modeling, Human and Organizational Behavior, Agent-Based Simulation, Adaptive Agents, Autonomous Agents

ANALYSIS OF ROUGH SURFACE LIGHTING BEHAVIORS WITH OPEN GL

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In the physical world, humans gather valuable information about objects through their sight. Information on shape, feel and composition are seen long before the object is touched. This information is generated by light reflecting off the surface of objects. Despite the advancement of computer graphics due to increased hardware rendering capacity, the fundamental equations, which draw three-dimensional scenes, lack the ability to truly model realistic objects. Whether it is smooth like highly polished metal or rough like the shag of a carpet, it is the reflection of light that tells humans what a surface feels like. The attempt taken in this thesis to implicitly model the roughness of textured surfaces through examination of an explicit model rendered with the OpenGL lighting equation. This approach has the potential to successfully increase the realism of computer graphics without increasing polygon count required for explicit surface generation. Through simulation of an explicitly constructed rough surface followed by the analysis of the behavior of its reflected light, the initial behaviors of textured surface reflections are identified. While these behaviors

are not enough to create corrections to the OpenGL lighting equation, they lay the foundation for further development.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation

KEYWORDS: Open GL Lighting Equation, Rough Surface Lighting Behaviors

THE EFFECTS OF NATURAL LOCOMOTION ON MANEUVERING TASK PERFORMANCE IN VIRTUAL AND REAL ENVIRONMENTS

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This thesis investigates human performance differences on maneuvering tasks in virtual and real spaces when a natural locomotion technique is used as opposed to an abstraction through a device such as a treadmill. The motivation for the development of locomotion devices thus far has been driven by the assumption that a "perfect" device will result in human performance levels comparable to the real world. This thesis challenges this assumption under the hypothesis that other factors beyond the locomotion device contribute to performance degradation. An experiment was conducted to study the effects of these other factors.

The experiment studied sidestepping, kneeling, looking around a corner, and backward movement tasks related to a building clearing exercise. The participants physically walked through the environment under all conditions. There were three treatments: real world (no display, physical objects present), virtual world (head-mounted display, no physical objects), and real and virtual world combined (head-mounted display, physical objects present).

The results suggest that performance and behavior are not the same across conditions with the real world condition being uniformly better than the virtual conditions. This evidence supports the claim that even with identical locomotion techniques, performance and behaviors change from the real to the virtual world.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation

KEYWORDS: Natural Locomotion, Virtual Environments

DYNAMIC SCALABLE NETWORK AREA OF INTEREST MANAGEMENT FOR VIRTUAL WORLDS

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A major performance challenge in developing a massively multi-user virtual world is network scalability. This is because the network over which entities communicate can quickly develop into a bottleneck. Three critical factors: bandwidth usage, packets per second, and network-related CPU usage, should be governed by the number of entities a given user is interested in, not the total number of entities in the world. The challenge then is to allow a virtual world to scale to any size without an appreciable drop in system performance.

To address these concerns, this thesis describes a novel Area of Interest Manager (AOIM) built atop the NPSNET-V virtual environment system. It is a dynamically sized, geographical region based, sender-side interest manager that supports dynamic entity discovery and peer-to-peer entity communication. The

AOIM also makes use of tools provided by the NPSNET-V system, such as variable resolution protocols and variable data transmission rate.

Performance tests have shown conclusively that these interest management techniques are able to produce dramatic savings in network bandwidth usage in a peer-to-peer virtual environment. In one test, this AOIM produced a 92% drop in network traffic, with a simultaneous 500% increase in world population.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation

KEYWORDS: Virtual Worlds, Network Scalability, NPSNET-V

IMPACT OF THE IMPLEMENTATION OF INFORMATION TECHNOLOGY ON THE CENTER FOR ARMY LESSONS LEARNED

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As today's Army moves further into the Information Age and its mission evolves into a CONUS-based, Fore Projection Army with diverse mission requirements, the ability to collect and disseminate lessons learned never has been more important. Units must be able to use the lessons of those soldiers who have preceded them in order to maximize force multipliers, execute missions, right the first time, and save lives.

This research evaluates the impact that the implementation of an Information Technology infrastructure has had on the efficiency of Army's Lessons Learned Process and the overall effectiveness of the Center for Army Lesson Learned to conduct its primary mission. The objective is to determine how Information Technology has changed the organizational structure, culture, reward systems, processes, and personnel skill requirements within CALL.

Research includes an in-depth review of CALL as the Army's mechanism for creating organizational learning, a description of the Lessons Learned Process, an efficiency comparison between the current and previous collection, an analysis of dissemination processes using Extend Simulation Software, and an explanation of the organization's current IT architecture.

DoD KEY TECHNOLOGY AREA: Manpower, Personnel, and Training

KEYWORDS: Learning Organization, Information Technology, Organizational Design, Center for Army Lessons Learned, Information Technology Architecture, Center for Army Lessons Learned, Collection and Observation Management Software

Institute for Defense Systems Engineering and Analysis (IDSEA)

STUDENT PROJECT

THE 'CROSSBOW' PROJECT

Naval Postgraduate School (NPS) students from across campus and from a variety of curricula recently completed a yearlong study and assessment of small, fast, surface combatants operating in large groups that are capable of distributed combat operations. The study effort required a level of interdisciplinary and interdepartmental collaboration not previously attempted at NPS. The final product is a concept called CROSSBOW, and is a strong demonstration of the School's ability to conduct large-scale investigations of relevant Navy issues.

THE 'CROSSBOW' TEAM

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Professors Emeriti Patrick Parker and Michael Sovereign
and other advisors for specialized supporting studies accomplished by SEI-2 students

The Project

The CROSSBOW project originated with the President of the Naval War College, who proposed studies to determine the technical feasibility and operational worth of CORSAIR -- a small, high-speed aircraft carrier concept. The central intent was to investigate the extent to which new technology and changing strategic environment warrant rethinking the relative merits of dispersion versus concentration and attendant economies of scale.

NPS elements contributing to the project are presented in Figure 1. The second cohort of students enrolled in the Systems Engineering and Integration (SEI) Curriculum were assigned CROSSBOW as their integration project. Students in the Total Ship Systems Engineering (TSSE) Capstone Ship Design Courses constituted the ship design team. The Capstone Aircraft Design Courses provided the air vehicle design team. Students from the Graduate School of Business and Public Policy produced a thesis on requirements and cost of CROSSBOW logistics and maintenance. A contributing thesis explored free electron lasers as "electric warship" weapons. In addition, the Operations Research Department tailored an existing campaign analysis course for the express purpose of evaluating a notional CROSSBOW force in scenarios representing the full spectrum of conflict. Also, the project benefited greatly from expertise and advice provided by the Electrical and Computer Engineering Department, as well as the Meteorology and Oceanography Department.

Allied officers made significant contributions to the CROSSBOW effort. Eight of the fifteen SEI students were combat officers from the Singapore Armed Forces. The eleven members of the ship design team included two naval officers from Turkey, one MOD civilian from Singapore and one naval officer from Greece. Finally, senior naval leadership, Navy and government laboratories, and industry visitors provided valuable insights.

The Concept

The NPS students chose to pursue a high-speed ship design that supports an air wing composed primarily of Unmanned Air Vehicles (UAVs). CROSSBOW combines a SEA LANCE (or "street fighter") variant (SEA LANCE II) with SEA ARCHER (a small, high-speed UAV Tactical Support Ship), and SEA QUIVER (a notional high-speed support ship). The SEA ARCHER air wing comprises 8 multi-mission SEA ARROWs, Unmanned Combat Air Vehicles (UCAVs), 8 multi-mission support UAVs, and 2 MH-60 multi-mission helicopters.

CROSSBOW was assessed for its capability to perform a wide variety of military missions. The students assessed the CROSSBOW force as being highly capable as (a) a complement to Carrier Battle Groups (CVBGs) in performing operations in the littorals in high-intensity combat scenarios, and (b) a supplement to CVBGs providing sea-based forward presence in low- to medium-threat environments. The students concluded: "CROSSBOW provides the stunning jab while the CVBG delivers the knockout punch."

In addition, the project considered cost, advantages of distributed combat capability, and technical feasibility. Estimates of the costs to acquire, operate, and support a CROSSBOW force of 32 ships and 144 aircraft appear reasonable: about 11.3 B (constant FY02 dollars) for acquisition and 410M per year in Operations and Support (O&S). The project also discovered significant benefits from distributed combat forces. These included a more diffuse center of gravity, which complicates enemy attacks on the force. Because of their relatively small size, SEA ARCHER and SEA LANCE II are "combat consumables," in that loss of one vessel does not constitute a catastrophic loss of overall combat capability. In addition, distributed combat forces have greater ability to mount multi-axis attacks, and therefore pose more difficult problems for an adversary.

While the technology to field CROSSBOW is not fully in hand at present, there is good reason to believe that it could be by 2012. Developing the technology could, in turn, result in a deployable CROSSBOW force in 2020. Studies and assessments of availability (and potential availability) of key technologies were pervasive in all aspects of the project. Technological issues were an integral part of the ship and air vehicle design projects. In addition, SEI students undertook a number of individual supporting studies of various technical issues – including command and control networks, automated ship operations, as well as means to defend against air, submarine and mine threats.

Bottom Line Conclusions

The project concluded that CROSSBOW is a highly promising concept. It has significant capabilities for a wide variety of naval missions – particularly in the littorals. The CROSSBOW force itself is highly flexible and can be a useful complement to a Carrier Battle Group. The depth of study the CROSSBOW project could undertake does not support an immediate and unqualified endorsement. However, the concept deserves serious consideration. It also warrants further exploration through development of relevant technologies and operational experimentation.

Also, the CROSSBOW project is an excellent example of NPS in its role as the Navy's Corporate University. NPS students, with faculty guidance and assistance, have undertaken interdisciplinary, integrated, imaginative, broad-gauge research of a topic that is both highly sensitive and very important. We believe the project convincingly demonstrates NPS ability to achieve educational excellence while simultaneously undertaking research that's relevant to the Navy's future.

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